Kornucopia® In Action!

- Experimental Data Analysis
- Penetration Event Correlation
- Recorded Kornucopia® Session
- Automated Tension Test Analysis
- General Purpose Averaging
- Aliasing – A Lurking Problem with Digital Data
- Correlating FEA and Experiments of LCD Ball Impact
- Sliding Mechanism Analysis
- FEA of Metal Bracket Failure
- WOX Shock Tester Development
- Salvaging Drifting Accelerometer Data with Highpass Filtering
- Sources of Noisy Data & Computing Derivatives of Noisy Data
- Not All DSP is the Same
- Comparing DSP Software
- Elastic-Plastic Material Calibration from Experimental Data
- Hyperfoam Material Modeling
- Automating Analysis of Hysteresis Data
- Kornucopia Improves Work-Flows that Use Data
- Handling Numerical Data and Text
- Mathcad is Powerful and Extendable
- Learning About & Accessing Kornucopia® Functionality is Easy
- Unique Training Courses

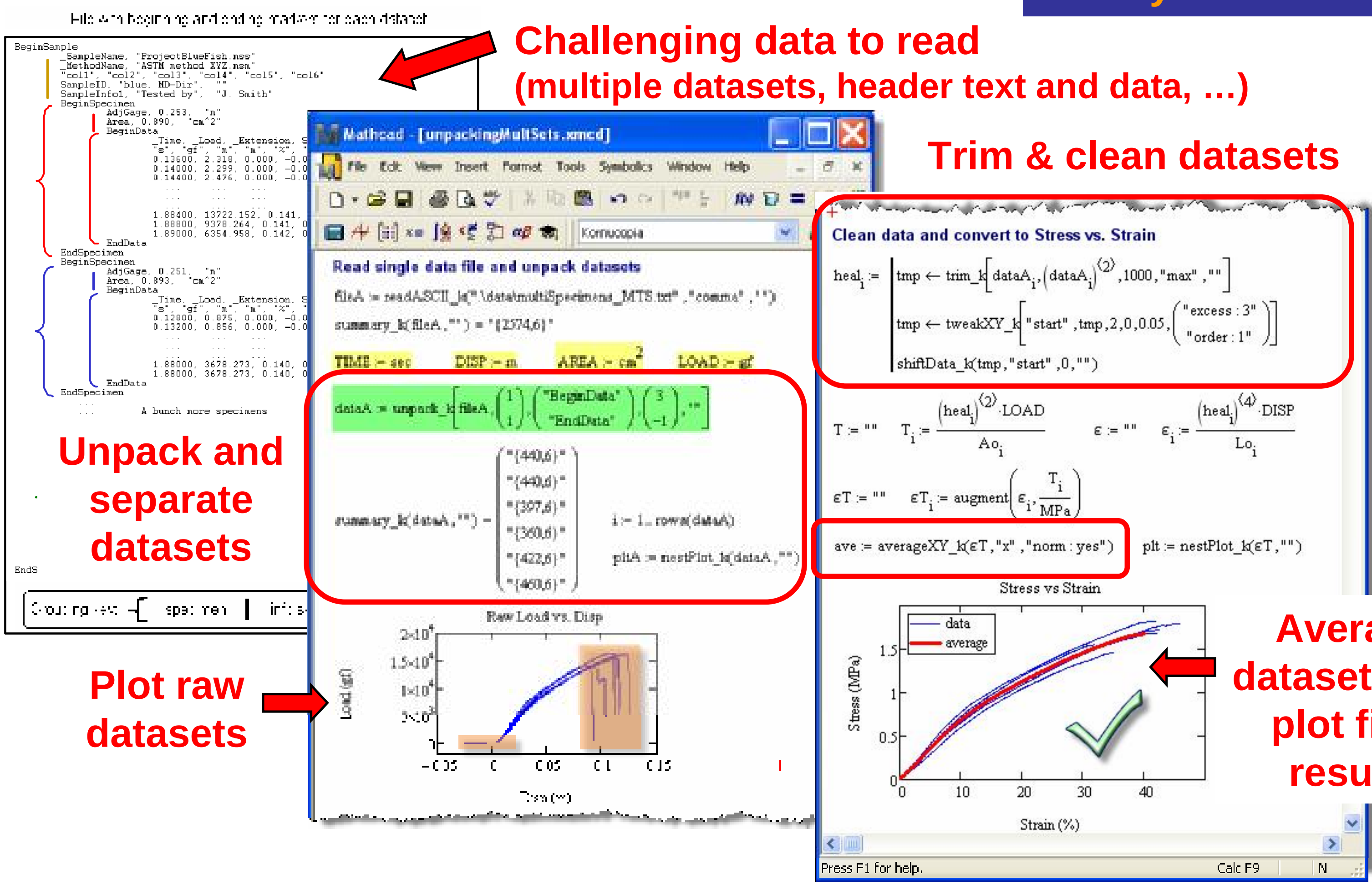
Typical Uses of Kornucopia®

Reusable, well documented Mathcad analysis worksheet

Processing Experimental Data

Challenging data to read
(multiple datasets, header text and data, …)

Trim & clean datasets



Unpack and separate datasets

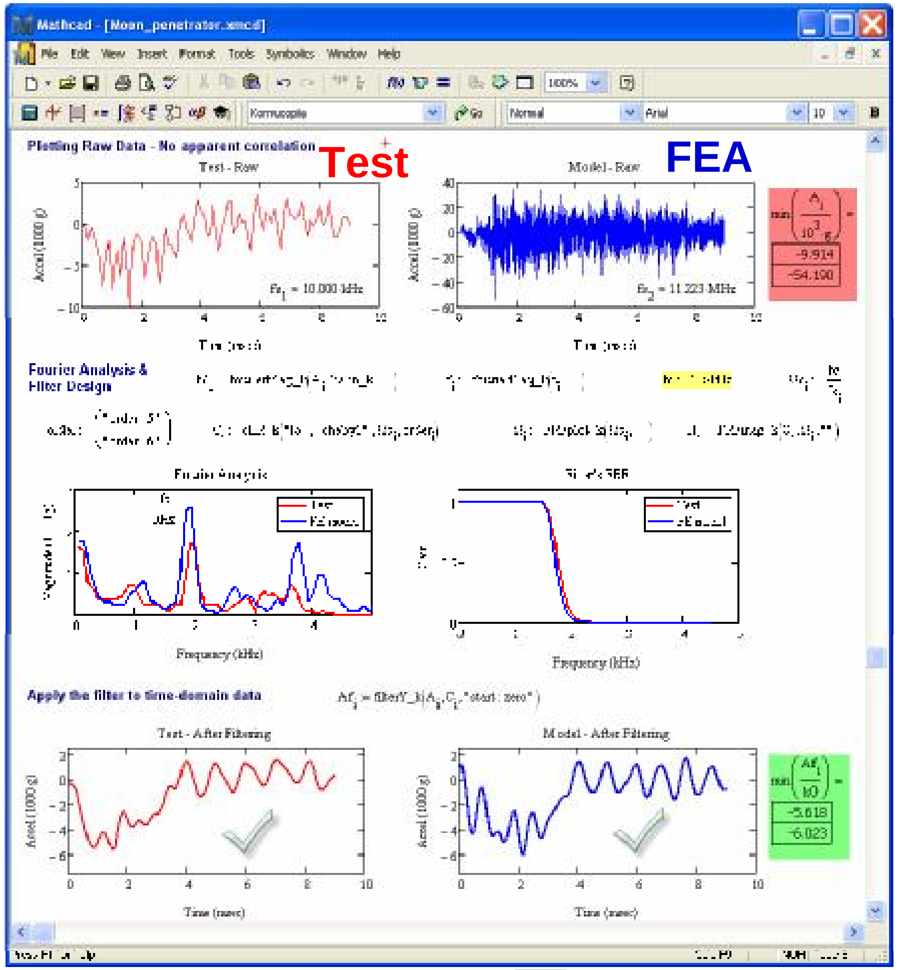
Plot raw datasets

Average datasets and plot final results

Typical Uses of Kornucopia®

Reusable, well documented Mathcad analysis worksheet

Analyzing Noisy FEA Results and Test Data



Challenging data from a penetration event

- **Initial comparison in time-domain**
- **Fourier Analysis to understand frequency content**
- **Filter to remove higher frequency differences**
- **Reassess filtered data in time-domain**

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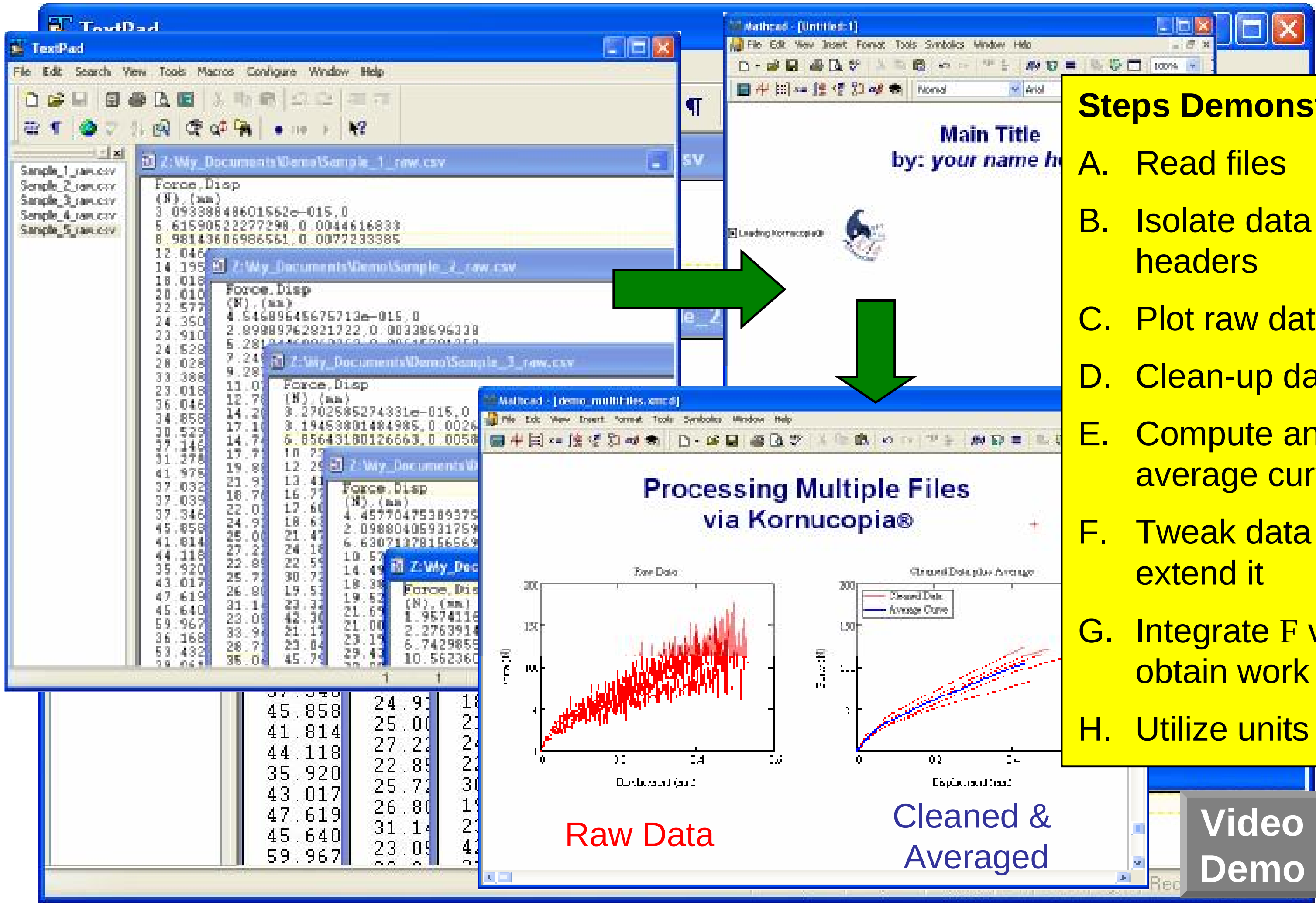
Kornucopia® - Powerful and Easy-To-Use Tools



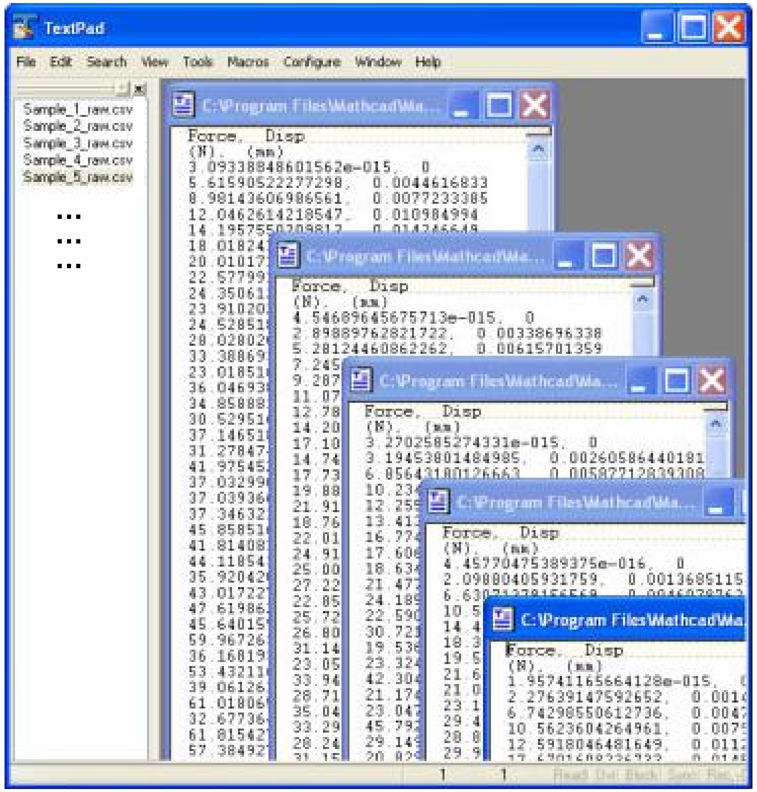
Steps Demonstrated

A. Read files
B. Isolate data & headers
C. Plot raw data
D. Clean-up data
E. Compute an average curve
F. Tweak data to extend it
G. Integrate F vs δ to obtain work
H. Utilize units

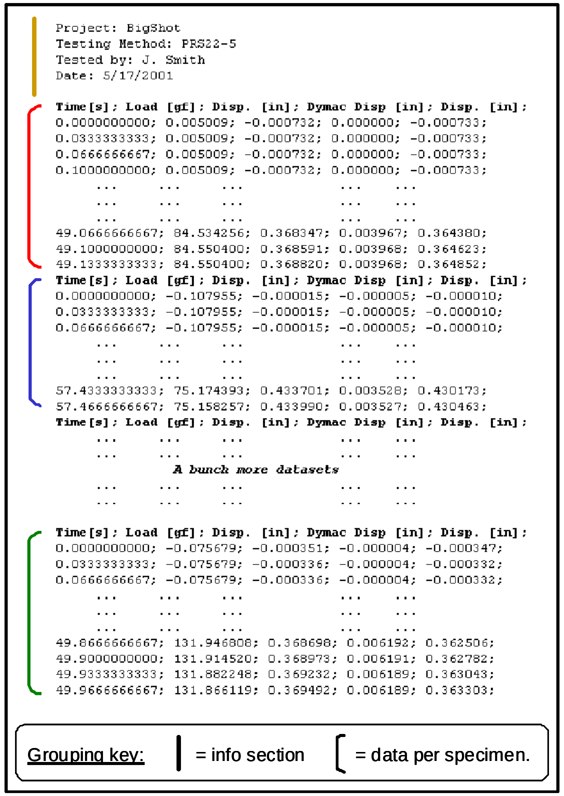
Video Demo

Kornucopia Readily Handles Large Amounts of Data

Numerous files with one or more specimens



One file, numerous specimens per file



```
Project: BigShot
Testing Method: PRS22-5
Tested by: J. Smith
Date: 5/17/2001

Time[s]; Load [gf]; Disp. [in]; Dymac Disp [in]; Disp. [in];
0.0000000000; 0.005009; -0.000732; 0.000000; -0.000733;
0.0333333333; 0.005009; -0.000732; 0.000000; -0.000733;
0.0666666667; 0.005009; -0.000732; 0.000000; -0.000733;
0.1000000000; 0.005009; -0.000732; 0.000000; -0.000733;
     ...      ...      ...           ...      ...
     ...      ...      ...           ...      ...
     ...      ...      ...           ...      ...
49.0666666667; 84.534256; 0.368347; 0.003967; 0.364380;
49.1000000000; 84.550400; 0.368591; 0.003968; 0.364623;
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     ...      ...      ...           ...      ...
     ...      ...      ...           ...      ...
57.4333333333; 75.174393; 0.433701; 0.003528; 0.430173;
57.4666666667; 75.158257; 0.433990; 0.003527; 0.430463;
Time[s]; Load [gf]; Disp. [in]; Dymac Disp [in]; Disp. [in];
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     ...      ...      ...           ...      ...
              A bunch more datasets
     ...      ...      ...           ...      ...
     ...      ...      ...           ...      ...

Time[s]; Load [gf]; Disp. [in]; Dymac Disp [in]; Disp. [in];
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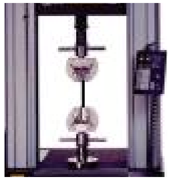
     ...      ...      ...           ...      ...
     ...      ...      ...           ...      ...
49.8666666667; 131.946808; 0.368698; 0.006192; 0.362506;
49.9000000000; 131.914520; 0.368973; 0.006191; 0.362782;
49.9333333333; 131.882248; 0.369232; 0.006189; 0.363043;
49.9666666667; 131.866119; 0.369492; 0.006189; 0.363303;
```

Grouping key: | = info section [= data per specimen.



Analyzing Tension Data

File with only beginning markers for each dataset

```
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Testing Method: PRS22-5
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0.0333333333; -0.107955; -0.000015; -0.000005; -0.000010;
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      ...      ...      ...              ...      ...
               A bunch more datasets
      ...      ...      ...              ...      ...
      ...      ...      ...              ...      ...

Time[s]; Load [gf]; Disp. [in]; Dymac Disp [in]; Disp. [in];
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0.0333333333; -0.075679; -0.000336; -0.000004; -0.000332;
0.0666666667; -0.075679; -0.000336; -0.000004; -0.000332;
      ...      ...      ...              ...      ...
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Analyzing Tension Data

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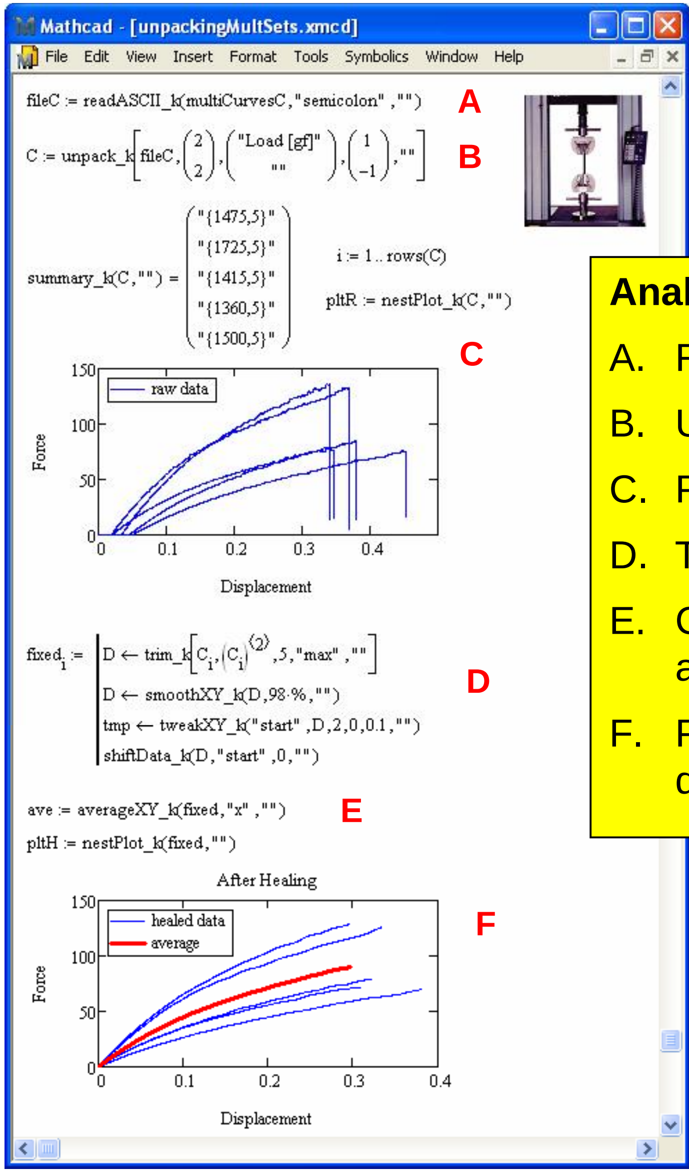

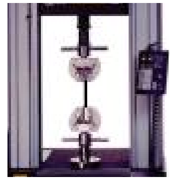

Analysis Steps

A. Read data file
B. Unpack data
C. Plot raw data
D. Trim & clean it
E. Compute an average curve
F. Plot cleaned data & average

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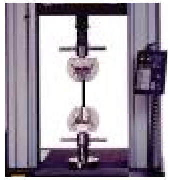
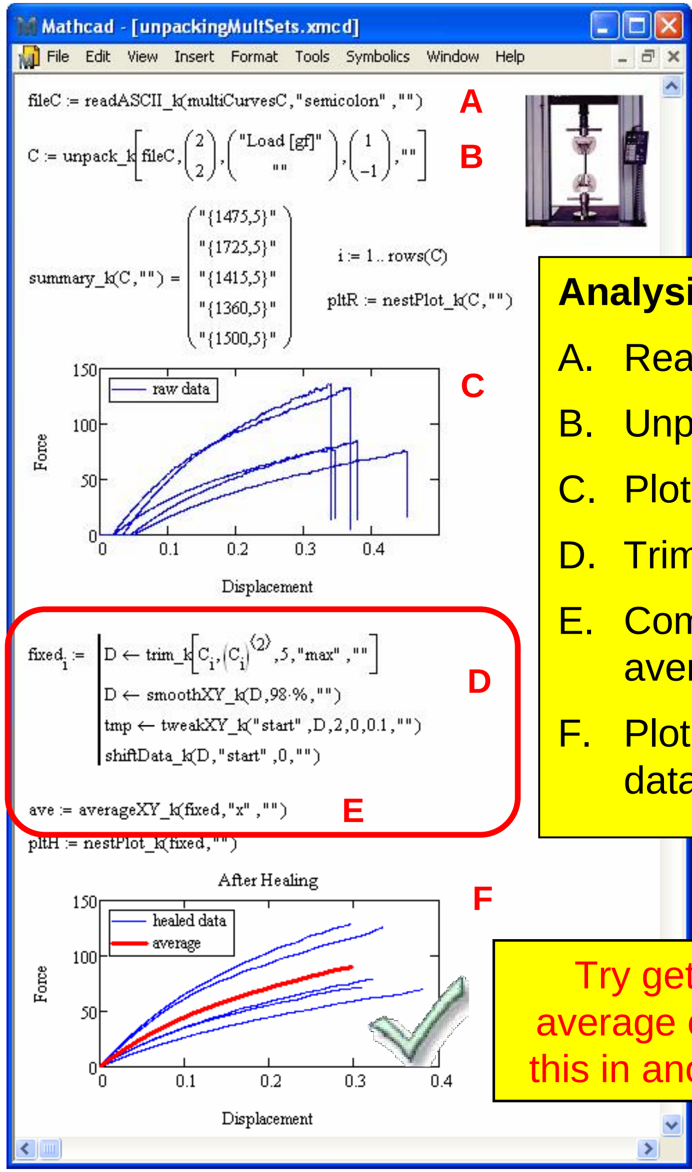
Analyzing Tension Data

Key Benefits:

- **Clear documentation of analysis process**
- **Reusable automated worksheet**
  - **Saves times**
  - **Reduces errors**
  - **Deployable to others**
- **Improved characterizations for:**
  - **Analytical Calculations**
  - **FEA Simulations**
  - **Quality Assurance**





Analysis Steps

A. Read data file

B. Unpack data

C. Plot raw data

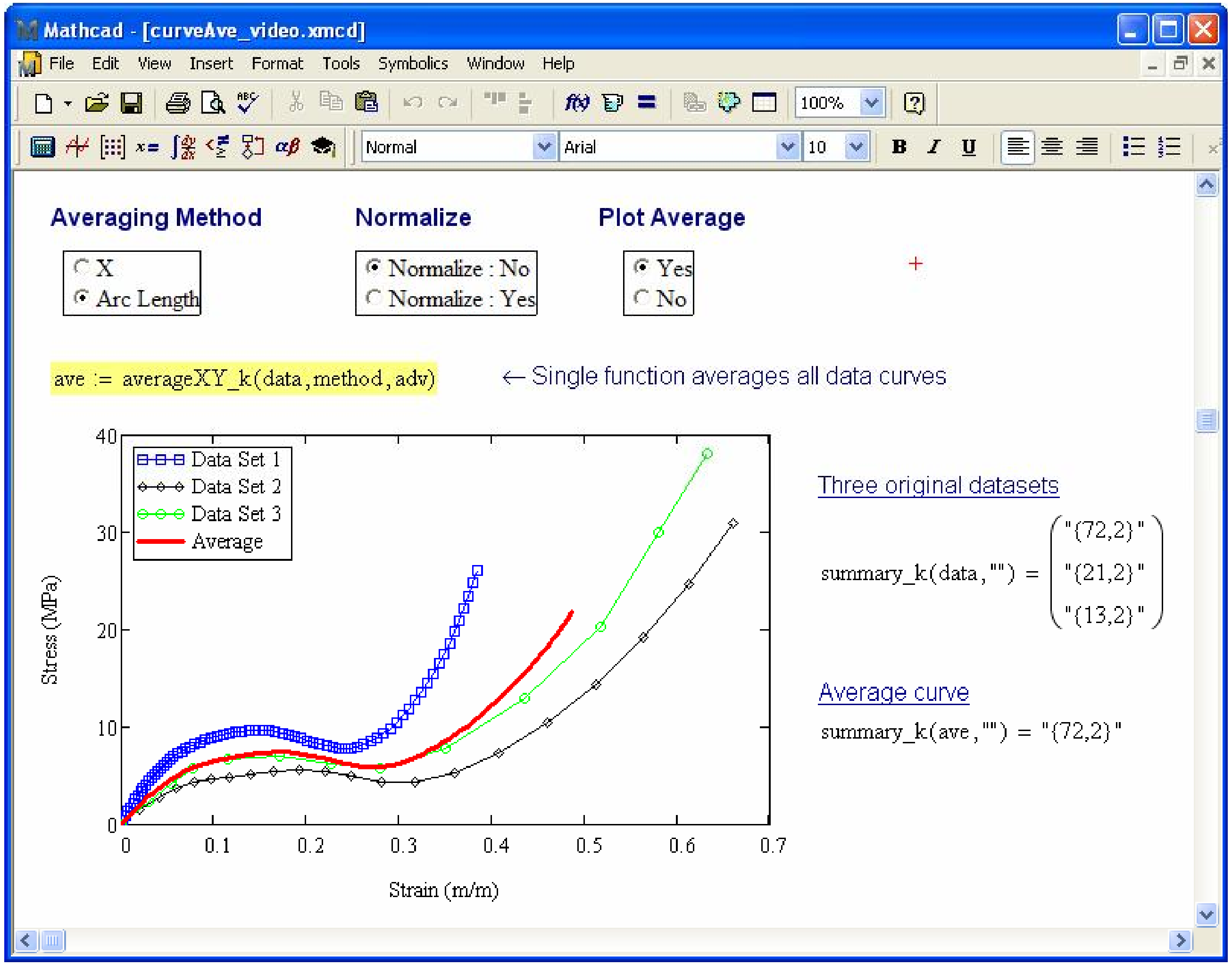
D. Trim & clean it

E. Compute an average curve

F. Plot cleaned data & average

Try getting an average curve like this in another tool!

General Purpose Averaging – A Powerful Feature



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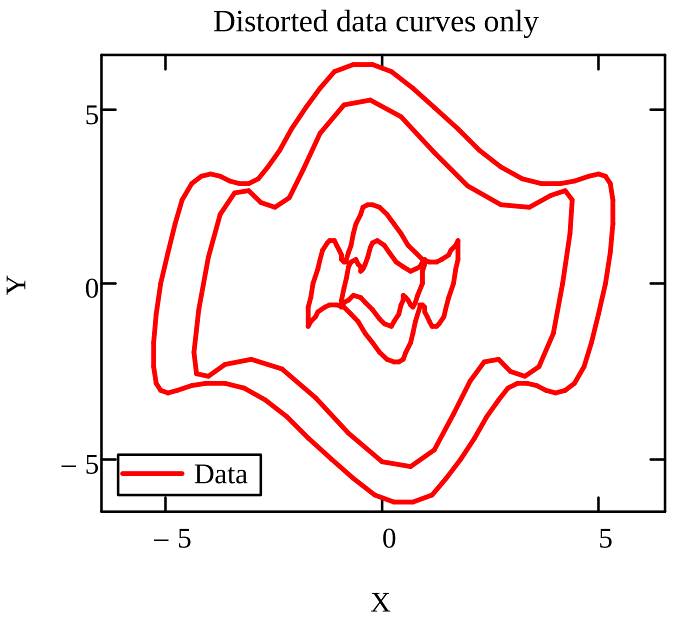
General Purpose Averaging

$$\text{summary\_k}(\text{Data}, \text{""}) = \begin{pmatrix} \text{"\{50,2\}"} \\ \text{"\{75,2\}"} \\ \text{"\{83,2\}"} \\ \text{"\{42,2\}"} \end{pmatrix} \text{m}$$

$\text{Data}_4 =$

	1	2
1	4.160	0.000
2	4.319	1.392
3	4.338	2.346
4	4.187	2.661
5	3.854	2.477
6	3.347	2.190
7	2.697	...

m

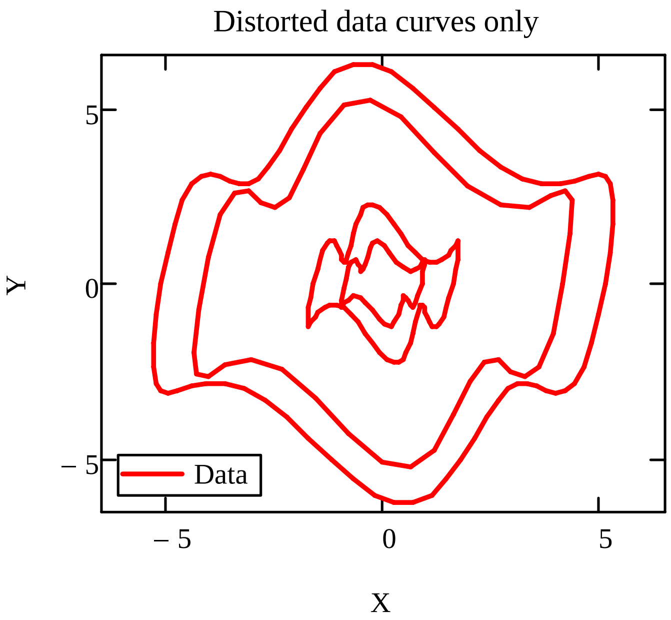


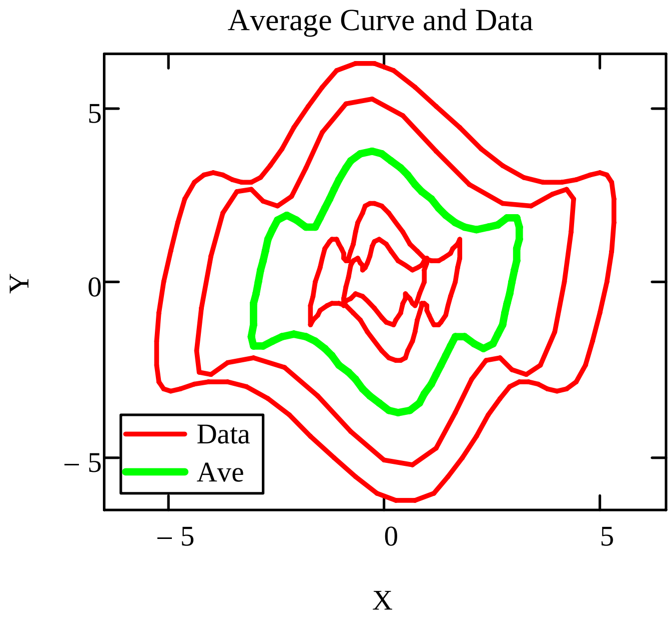
What is the average of this set of 4 data curves?

General Purpose Averaging

$$\text{summary\_k(Data,"")} = \begin{pmatrix} \text{"\{50,2\}"} \\ \text{"\{75,2\}"} \\ \text{"\{83,2\}"} \\ \text{"\{42,2\}"} \end{pmatrix} \text{m}$$

Ave := averageXY_k(Data, "arc" , "norm : yes")





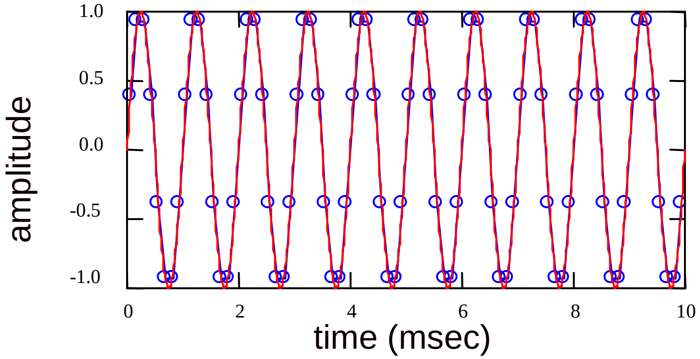
Aliasing – A Lurking Problem with Digital Data

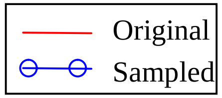
$A(t) = a_o \cdot \sin(2\pi \cdot f_o \cdot t)$

f_o = 1.0 kHz

f_o = 1.0 kHz

8 increments per period, $f_s = 8.0\, f_{max}$





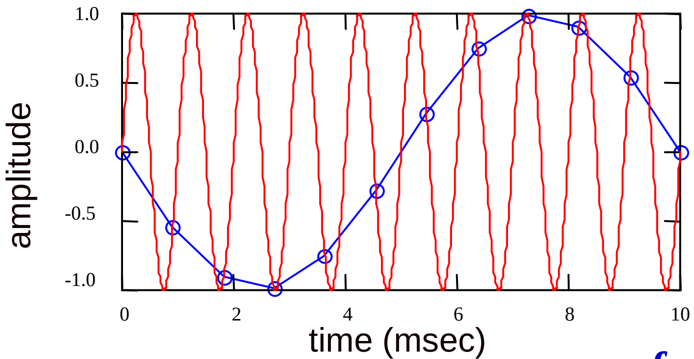
To avoid aliasing

$$f_s > 2\, f_{max}$$

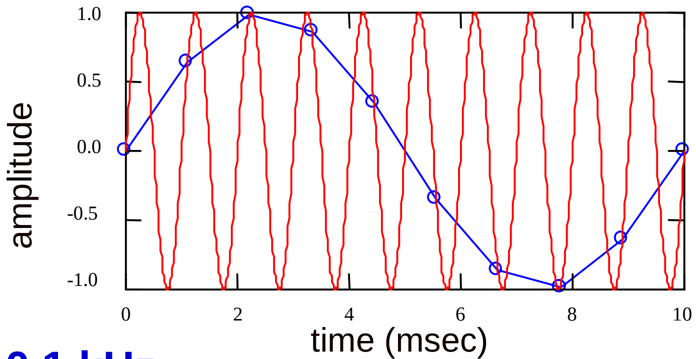
Satisfying the sampling theorem avoids aliasing

Violating the sampling theorem creates aliasing

1.1 increments per period, $f_s = 1.1\, f_{max}$



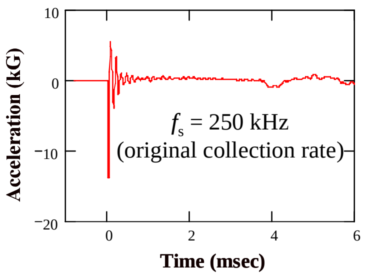
0.9 increments per period, $f_s = 0.9\, f_{max}$

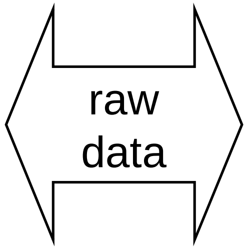


f_{alias} = 0.1 kHz

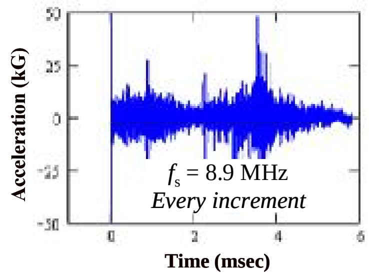
Examples of Noisy and Challenging Data

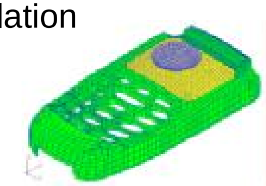
Experimental measurement





Explicit Dynamics FEA Simulation



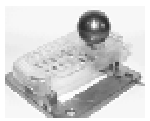


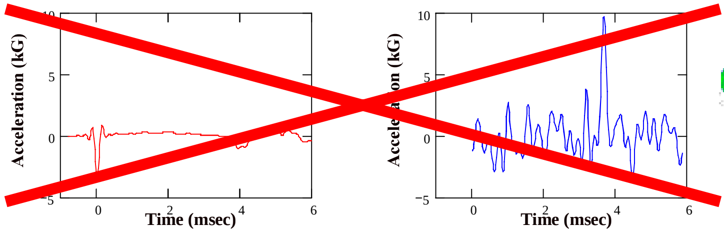
Cell phone lens impact

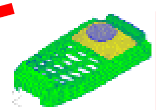
Why do 2 engineers find completely different results starting with same data?

- Result after lowpass filtering with 6th-order Butterworth filter, 5 kHz cutoff.

Typical result of Experiment/CAE comparison (improper or no DSP training)



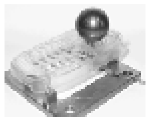


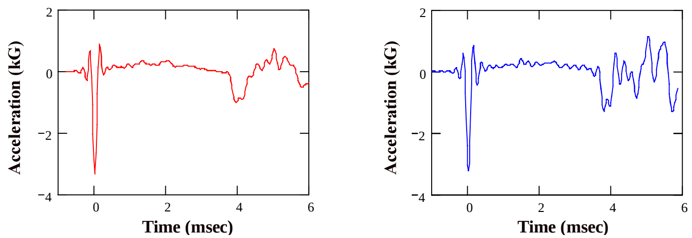


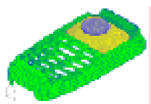
Sample rate of data in all 4 plots: 50-kHz

Note different Y-axis limits

Improved Experiment/CAE comparison (proper DSP usage)







Engineer A

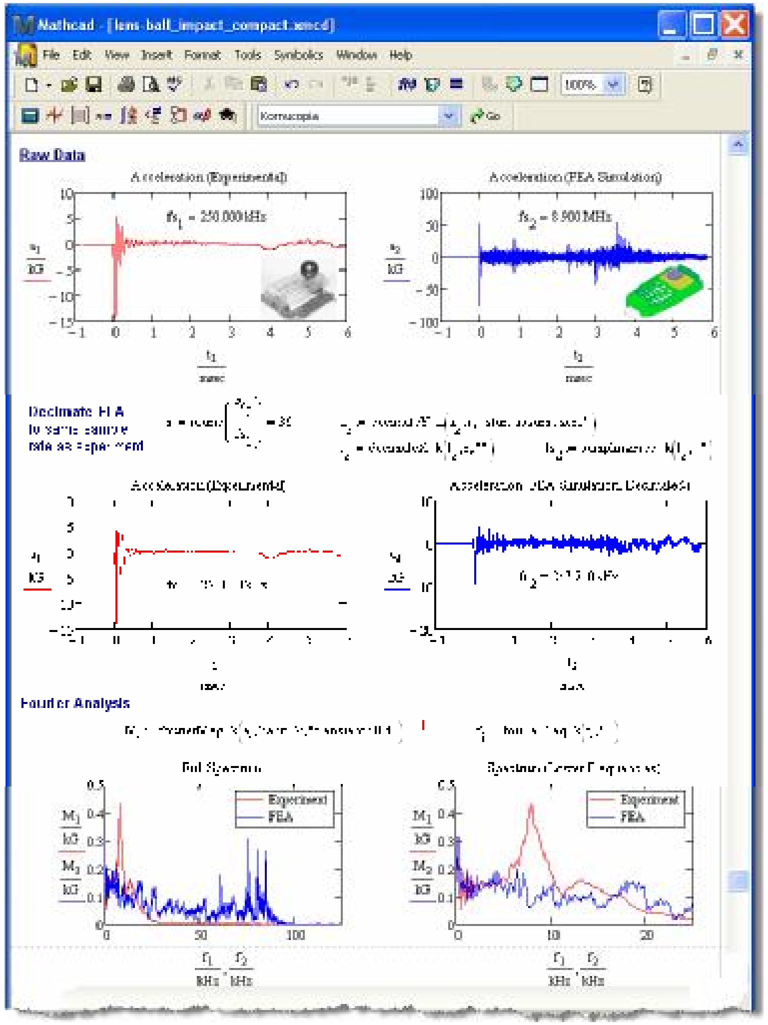
"NO correlation"

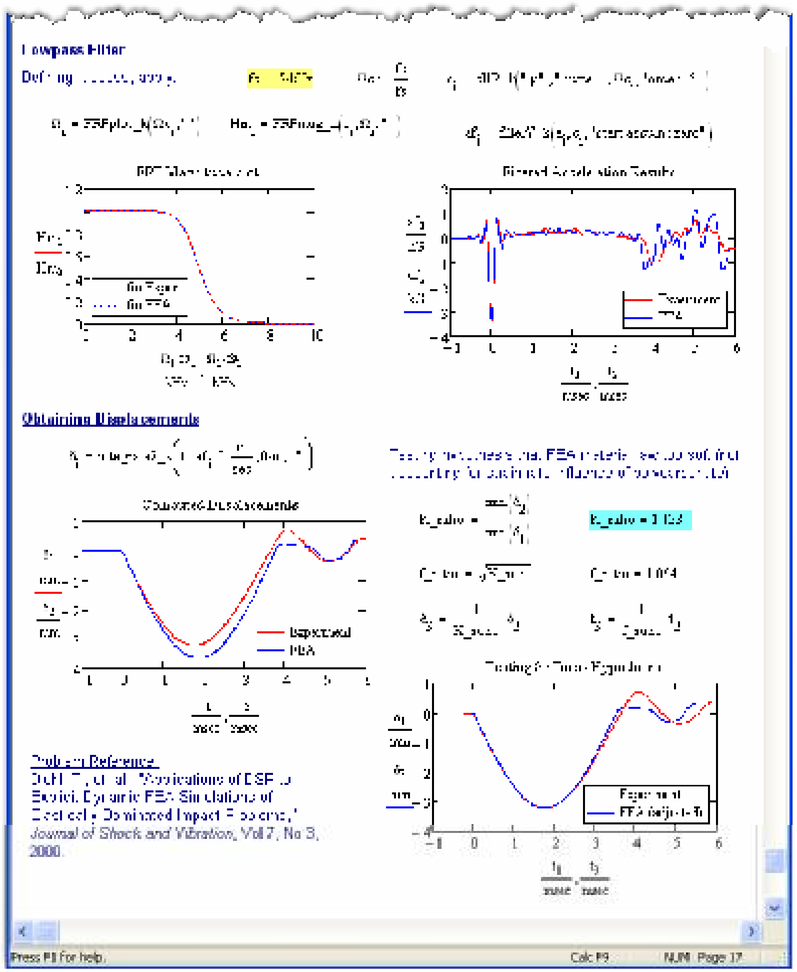
Aliasing distorted analysis

Engineer B

"Good Match"

Kornucopia® Improves Analysis of Challenging Data





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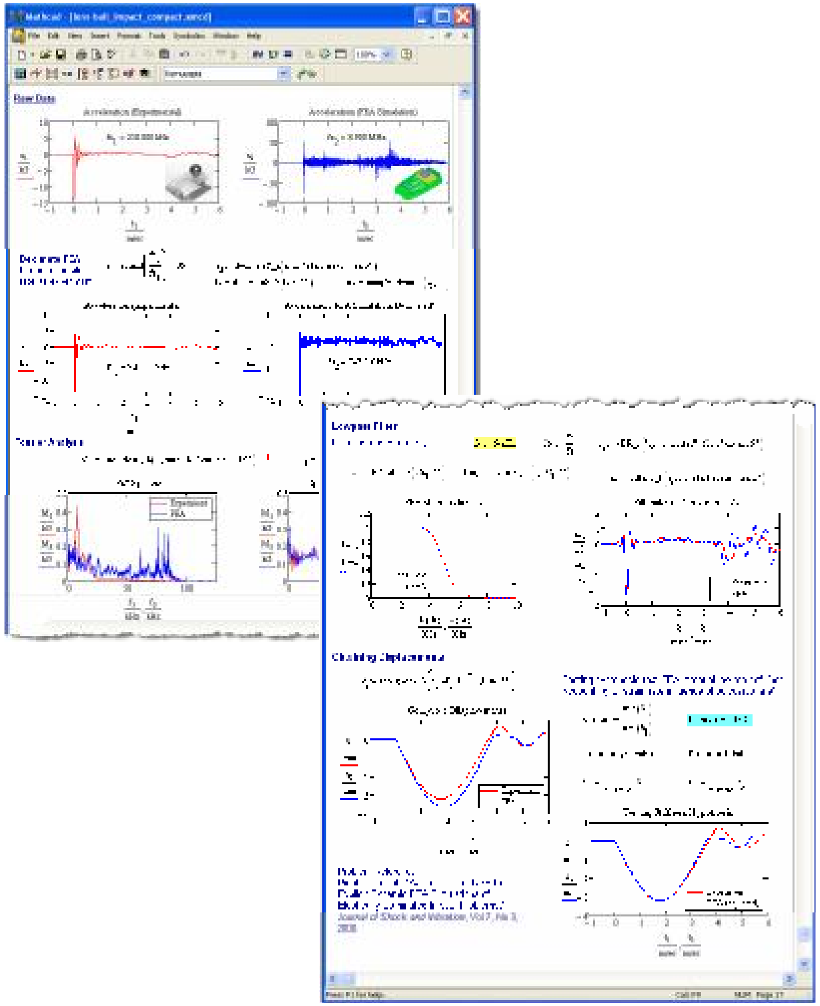
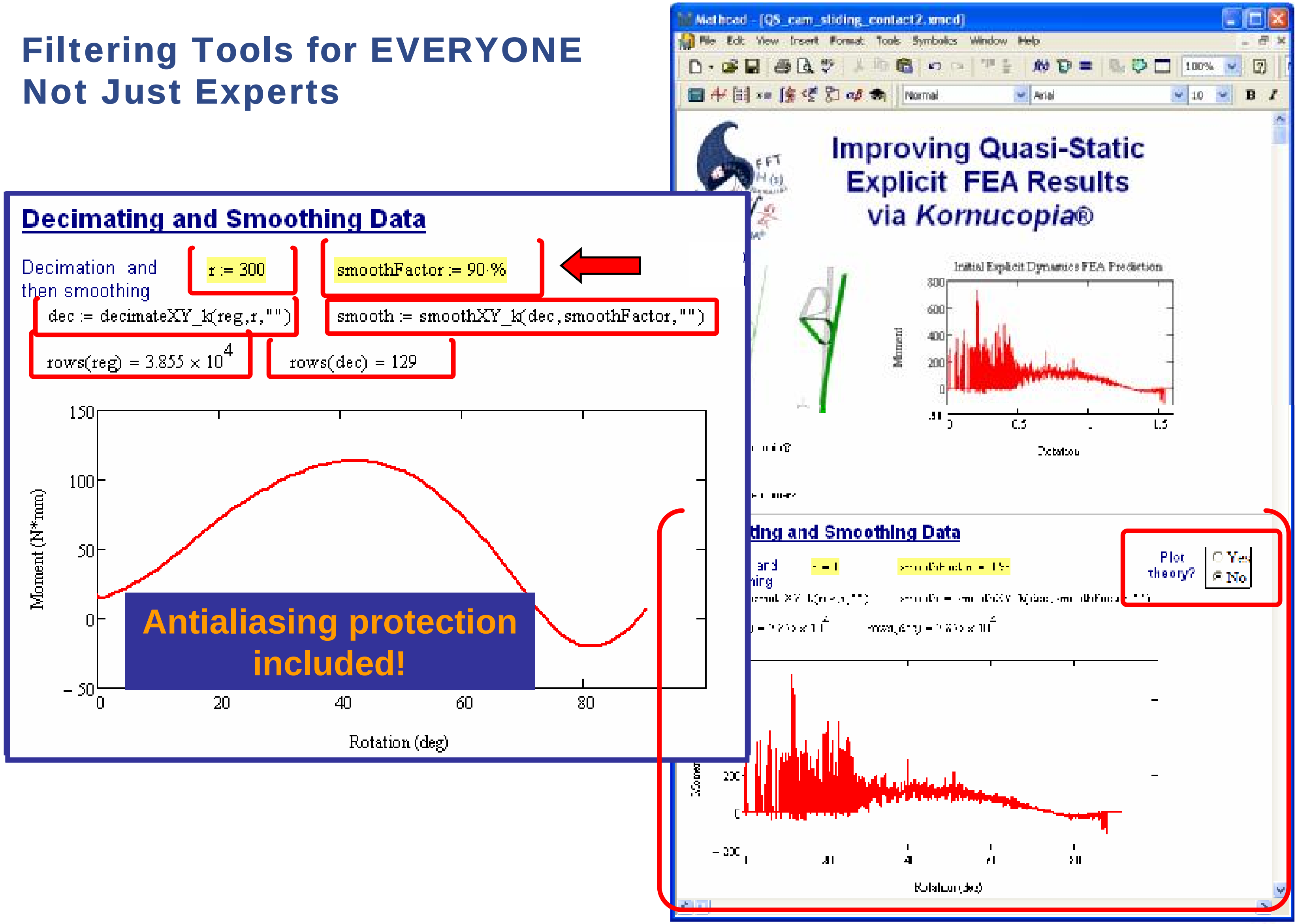
Kornucopia® Improves Analysis of Challenging Data

Key Benefits:

- **Clear documentation of analysis process**
- **Reusable automated worksheet**
  - **Saves times**
  - **Reduces errors**
  - **Deployable to others**
- **Confidence in both Testing and Modeling Approach**
  - **They Correlated!**
- **Improved FEA material law via stiffness correction factor**



Filtering Tools for EVERYONE
Not Just Experts



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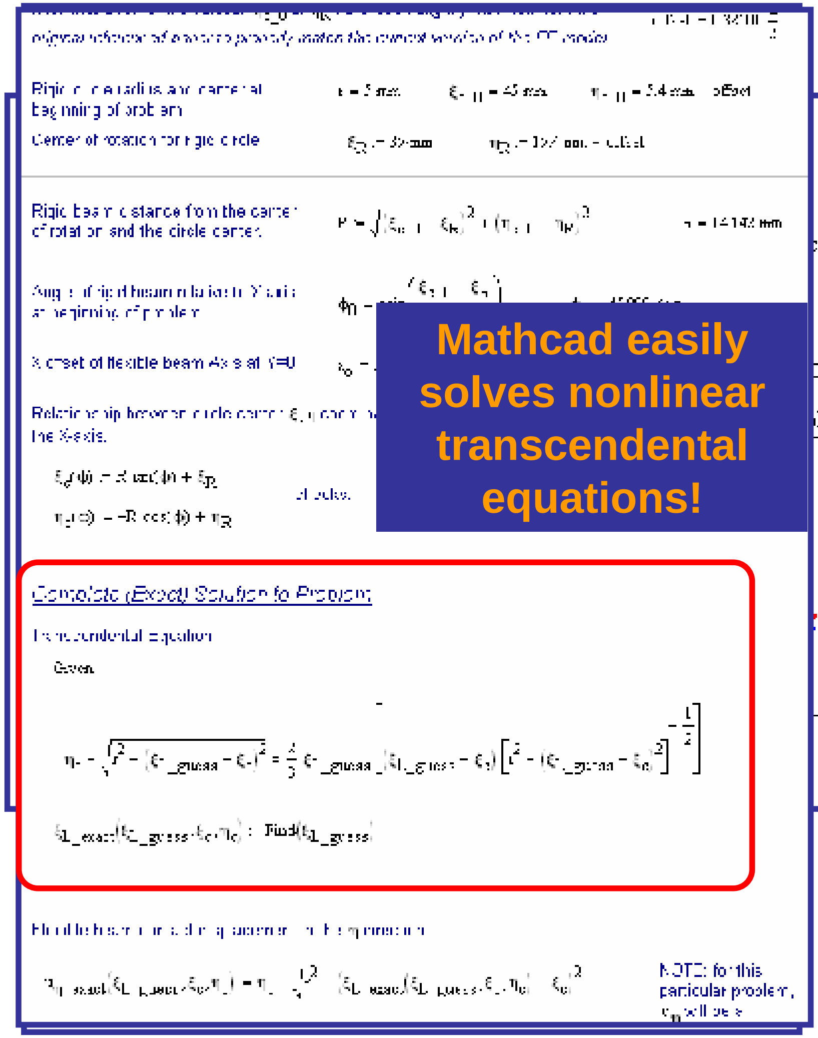
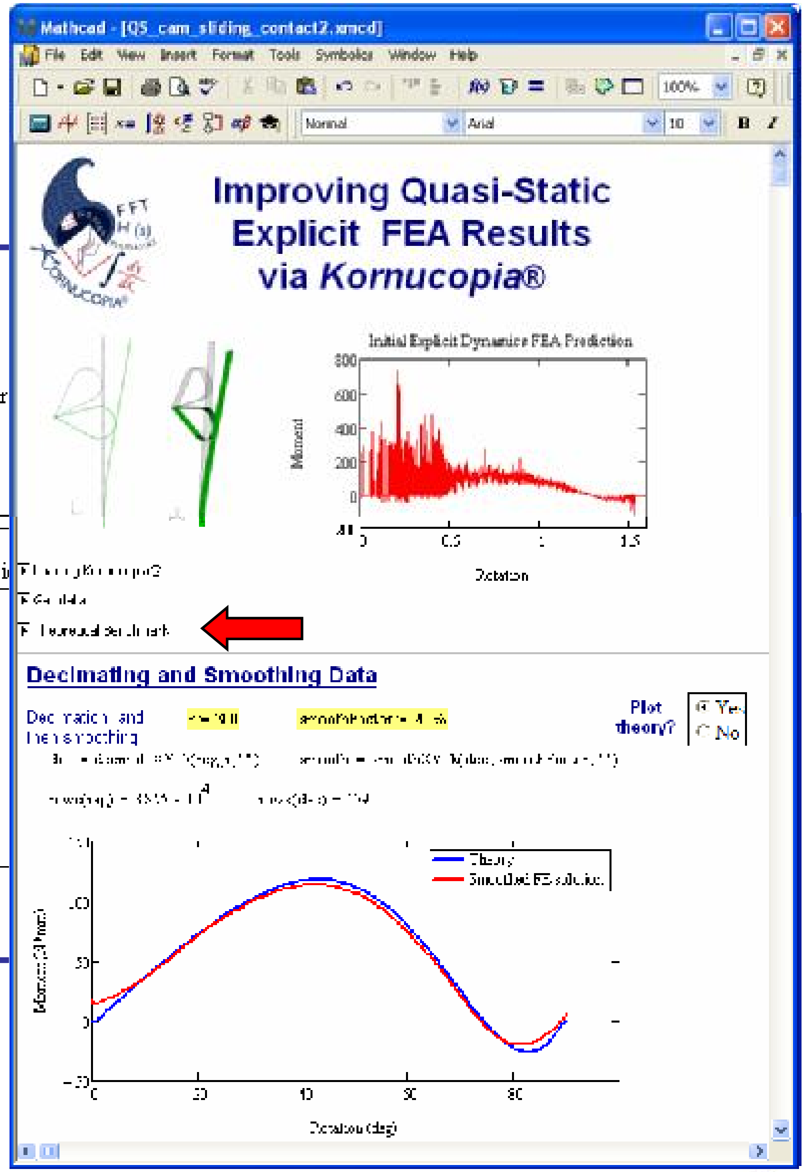
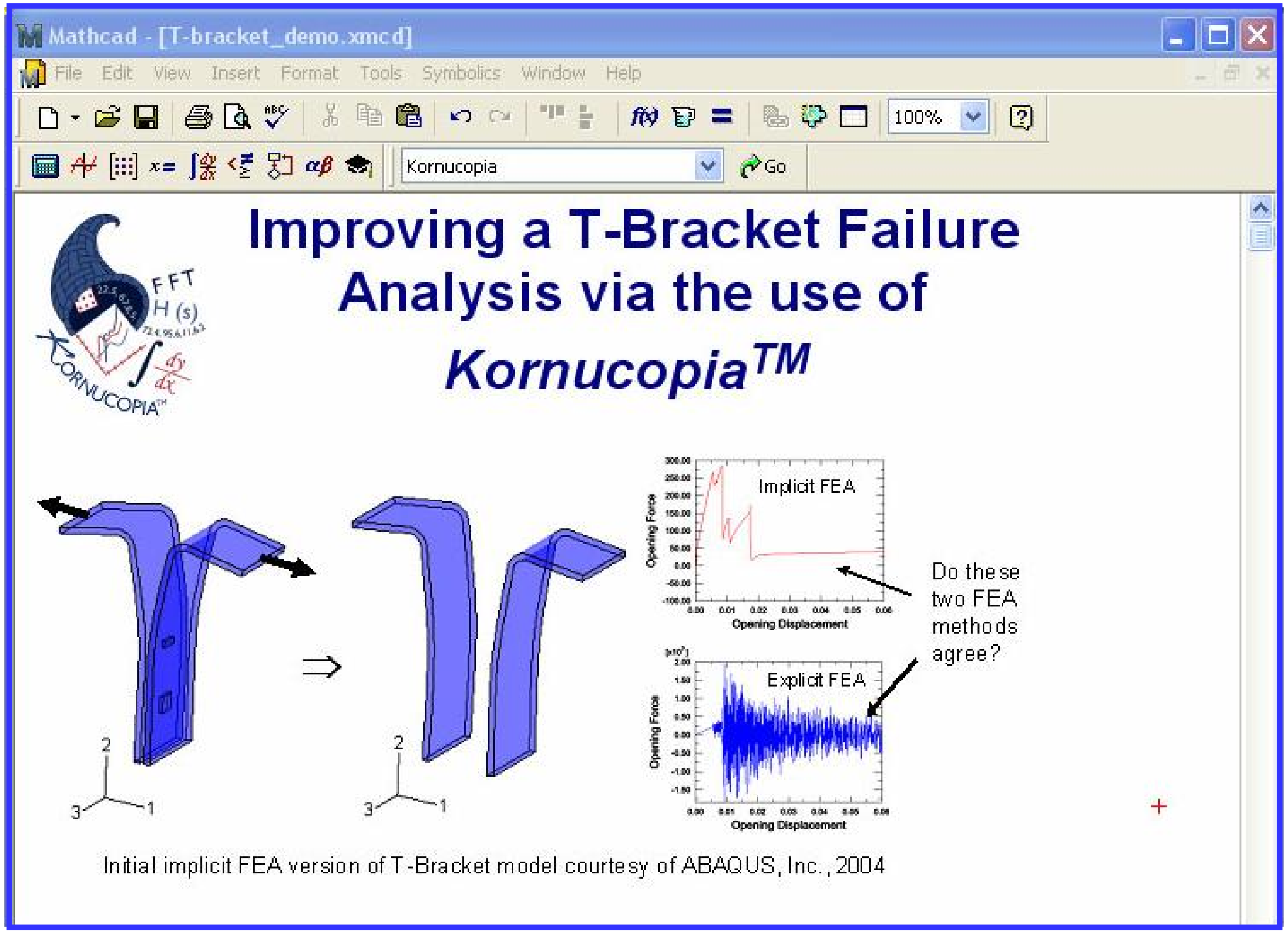


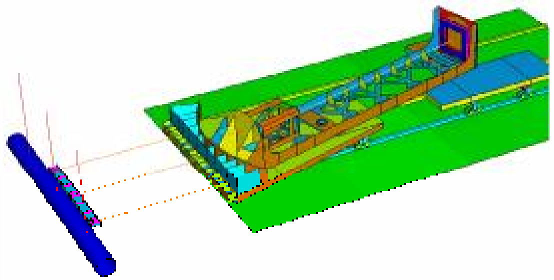


T-bracket Failure Analysis



Development of Naval Surface Warfare Center WOX Shock Tester

- Analysis of Abaqus/Explicit FEA model of a Missile Shock Test Machine at NSWC, Dahlgren Division
- Perform 50+ DOEs
  - 30 output sensors: ~50,000 rows, 31 cols
  - Decimate, LP filter, find local max/min velocities & mean acceleration over several regions.



names = ("model1.rpt", "model2.rpt", "model3.rpt")

i := 1 .. rows(names)

data = ({2511,31}, {2502,31}, {2498,31})

Select sensors of interest

sensors := reorder_k[sensors,"keep","cols",(1 5 13 6),""]

$data_i$:= reorder_k[$data_i$,"keep","cols",(1 5 13 6),""]

$sensors^T$ = ("Time", "TopRear, X", "Front, X", "TopRear, Y")

Perform DSP

fs_i := samplingFreq_k[$(data_i)^{\langle 1\rangle}$·sec,""]

fs = (10.043, 10.006, 9.956)·kHz

Define cutoff frequency

fc := 50·Hz

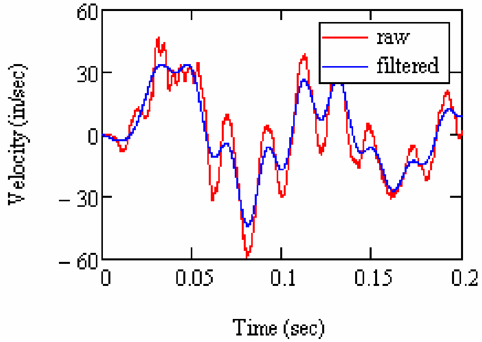
C_i := cIIR_k("lp","butter",$\frac{fc}{fs_i}$,"")

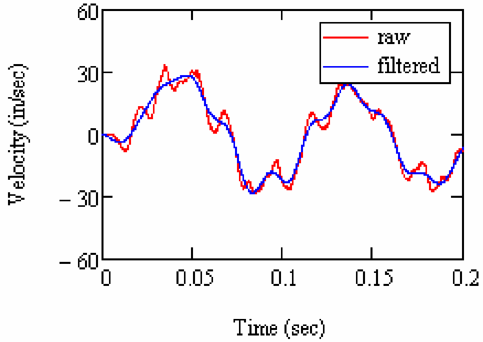
$dataf_i$:= filterXY_k($data_i$,C_i,"start assump : zero")

select a sensor to view s := 4 $sensors^{\langle s\rangle}$ = ("TopRear, Y")

set_a := 1 $names_{set_a}$ = "model1.rpt"

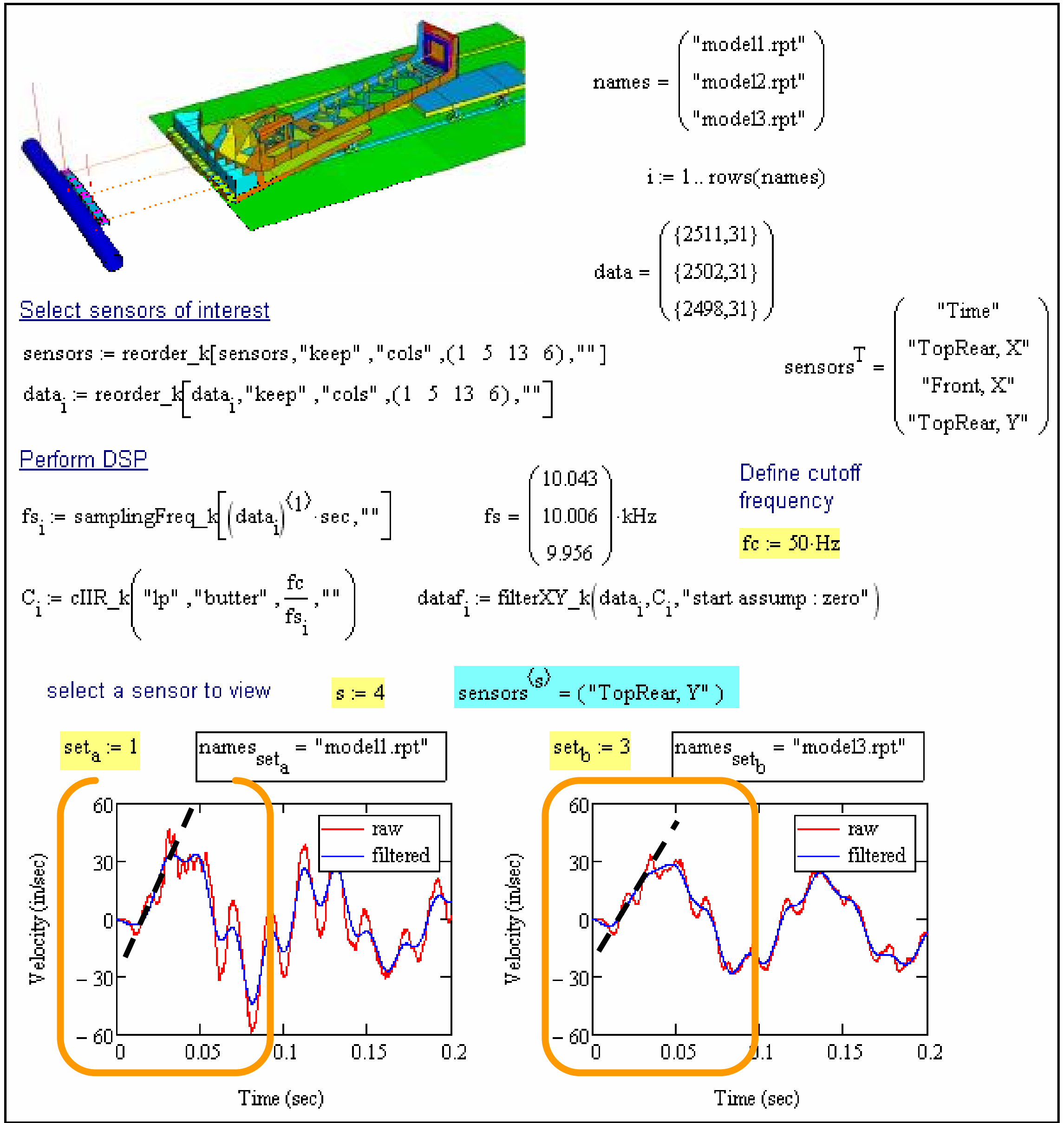
set_b := 3 $names_{set_b}$ = "model3.rpt"



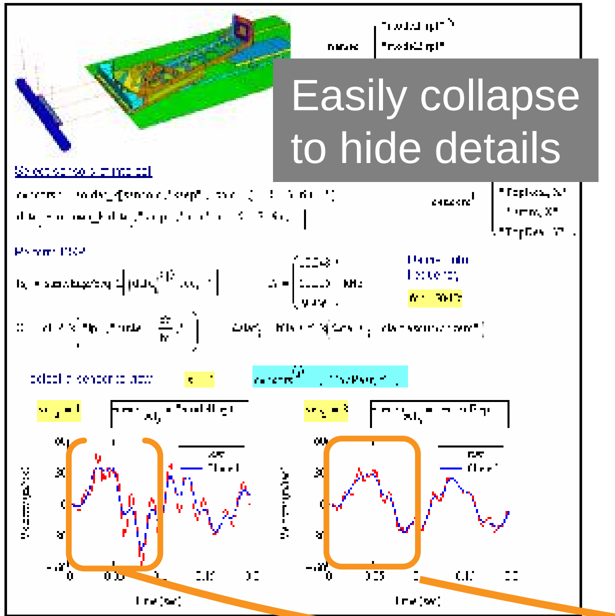


Development of Naval Surface Warfare Center WOX Shock Tester

- Analysis of Abaqus/Explicit FEA model of a Missile Shock Test Machine at NSWC, Dahlgren Division
- Perform 50+ DOEs
  - 30 output sensors: ~50,000 rows, 31 cols
  - Decimate, LP filter, find local max/min velocities & mean acceleration over several regions.



Development of Naval Surface Warfare Center WOX Shock Tester



Analysis of WOX Shock Tester with permission from Jon Yagla, Naval Surface Warfare Center, Dahlgren Div.

Specify a rough maximum time trigger $tmax := 0.1$

Specify minimum velocity trigger $trigger := 5$

counter to loop through sensors $j := 2 .. cols(dataf_1)$

Trim out the data section in each curve to be analyzed

$$analyze_{i,j} := \left| \begin{array}{l} rough \leftarrow trim\_k\left[dataf_i, \left(dataf_i\right)^{\langle 1 \rangle}, "", tmax, ""\right] \\ trim\_k\left(rough, rough^{\langle j \rangle}, trigger, "max", ""\right) \end{array} \right.$$

Assigning time and sensor velocity variables $t_{i,j} := \left(analyze_{i,j}\right)^{\langle 1 \rangle}$ $V_{i,j} := \left(analyze_{i,j}\right)^{\langle j \rangle}$

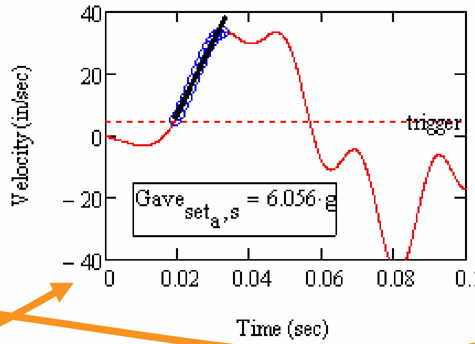
Computing mean acceleration values

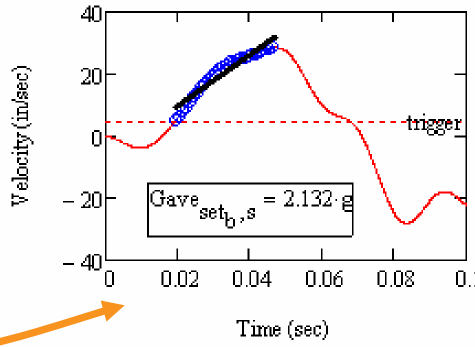
$$Gave_{i,j} := slope\left(t_{i,j} \cdot sec, V_{i,j} \cdot \frac{in}{sec}\right)$$

$$Gplot(t, V) := \left| \begin{array}{l} M \leftarrow slope(t, V) \\ B \leftarrow intercept(t, V) \\ M \cdot t + B \end{array} \right.$$

$$Gplt_{i,j} := Gplot\left(t_{i,j}, V_{i,j}\right)$$

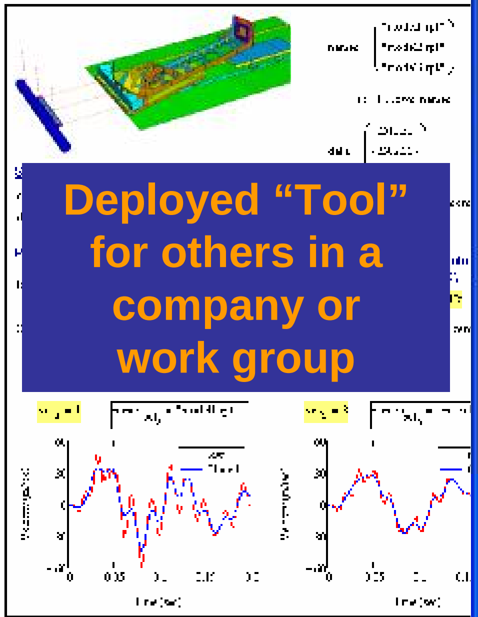
$names_{set_a} = "model1.rpt"$ $sensors^{\langle s \rangle} = ("TopRear, Y")$ $names_{set_b} = "model3.rpt"$

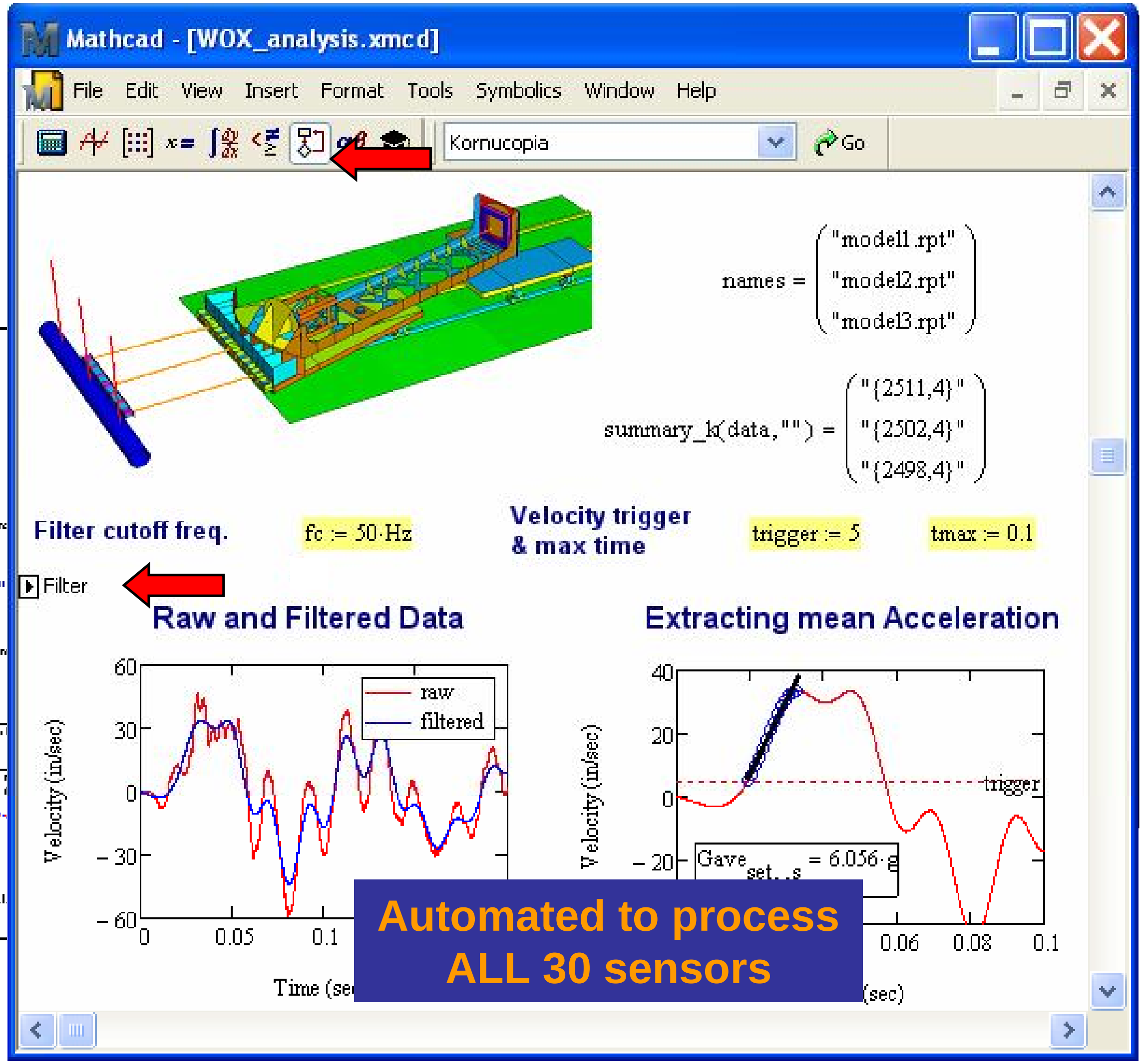




Acceleration Summary (units = g)			
	TopRear, X	Front, X	TopRear, Y
model1.rpt	8.67	24.69	6.06
model2.rpt	1.00	20.81	2.15
model3.rpt	0.99	20.78	2.13

Development of Naval Surface Warfare Center WOX Shock Tester

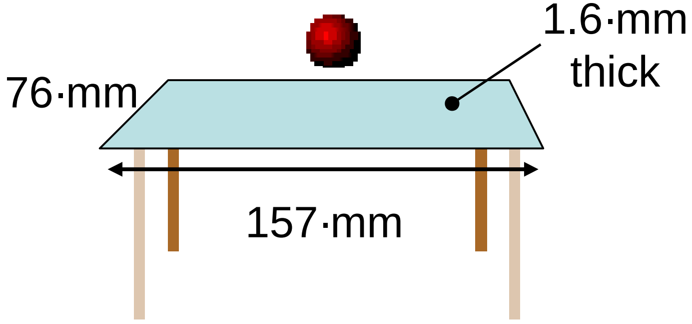




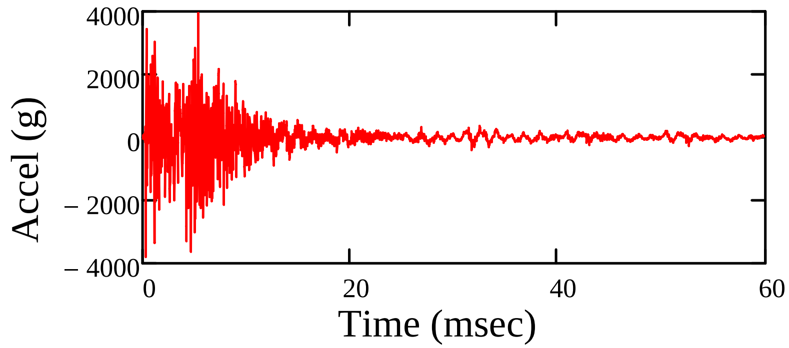
Analysis of WOX Shock Tester with permission from Jon Yagla, Naval Surface Warfare Center, Dahlgren Div.

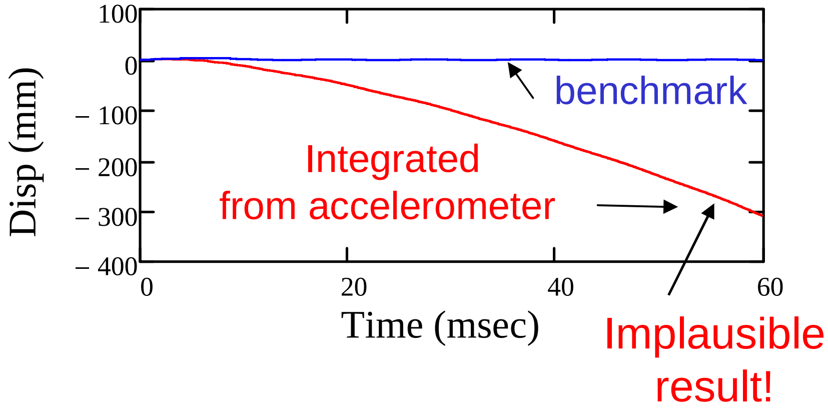
Integrating Acceleration Data – Another Big Challenge!

Why does this measured acceleration produce a ridiculous displacement?



Steel ball impacting aluminum plate



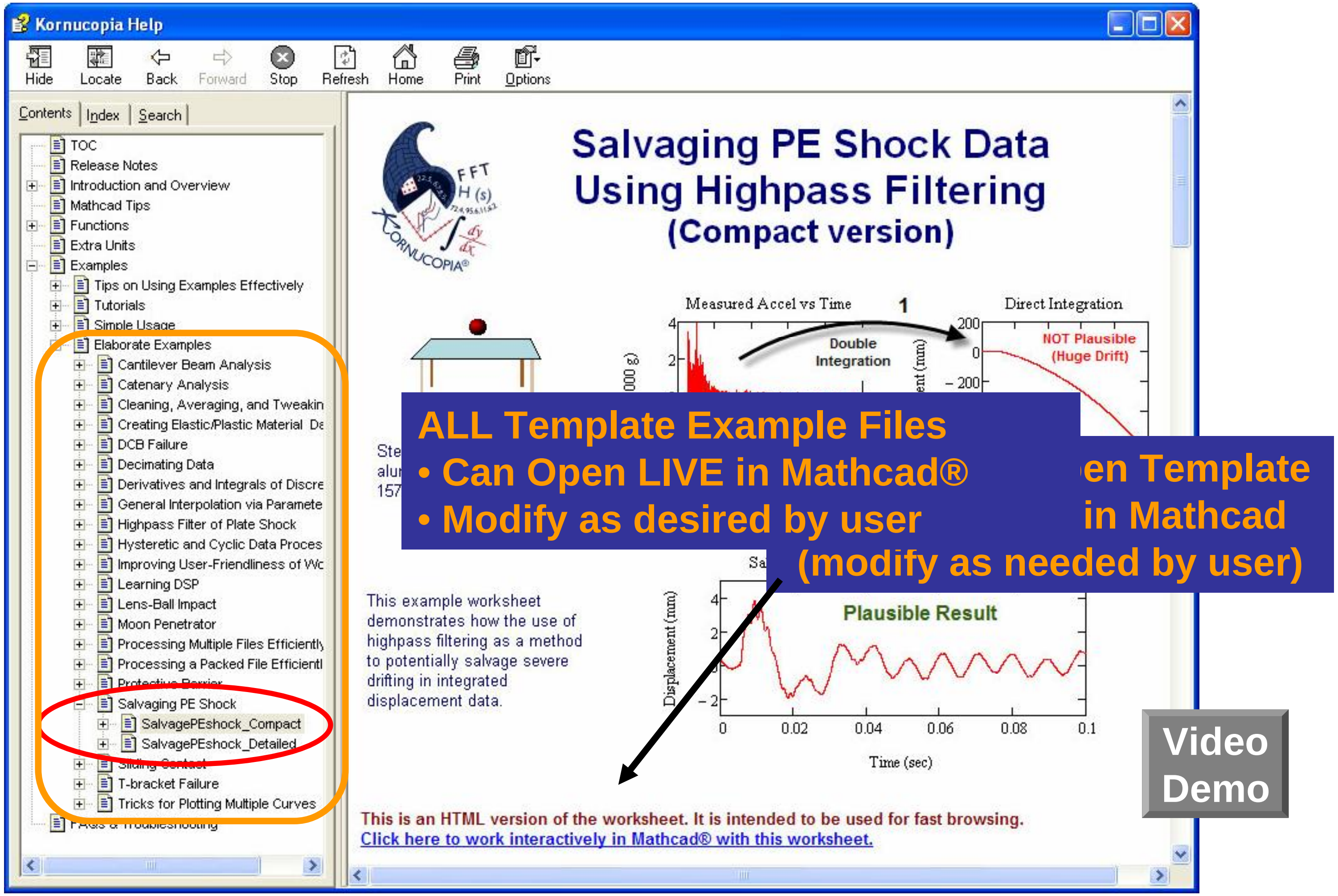


Answer:

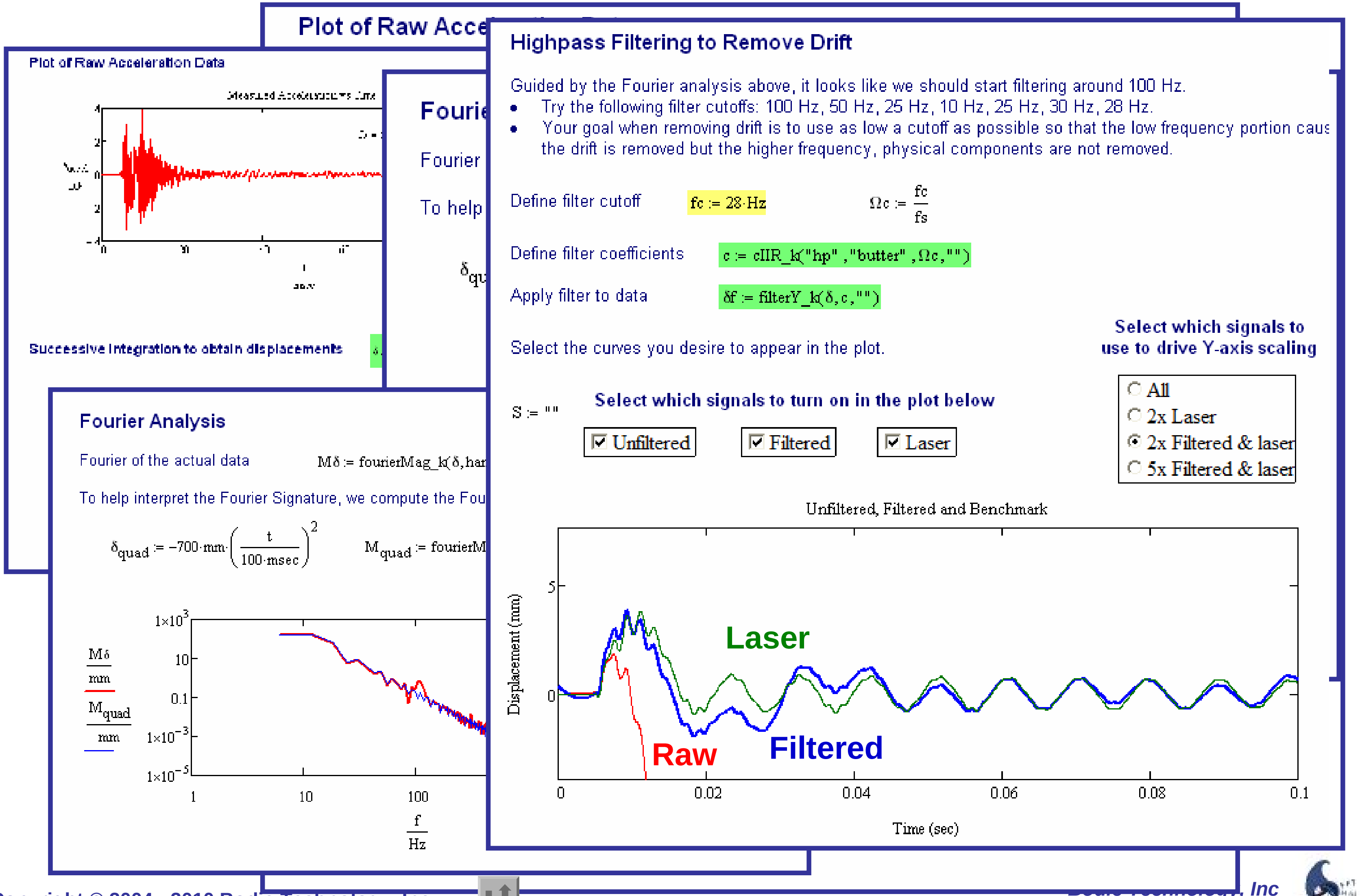
Low frequency distortion in accelerometer data

- Very common with measured data

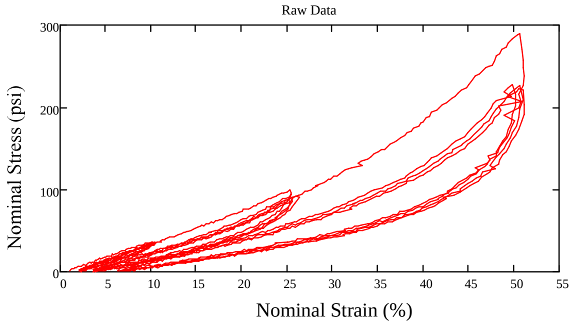
Example Templates in Library Help Meet the Challenge!



Integrating Acceleration Data – Another Big Challenge!

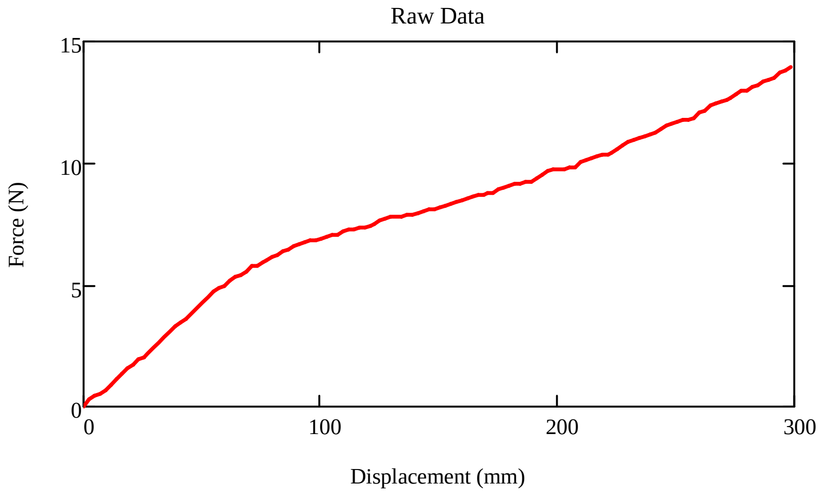


Noisy and Challenging Data



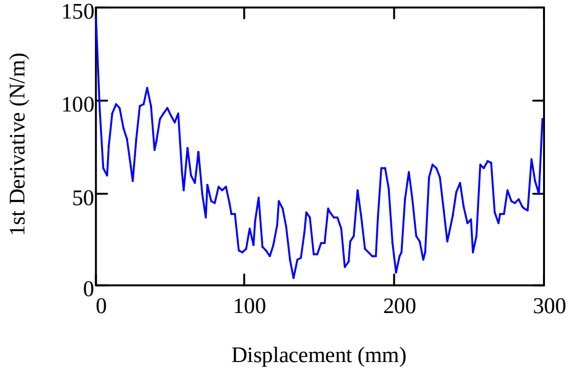
- **Comes from many sources & for many reasons**
  - Physical and artificial
  - Measurements and simulations
- **Found in many places**
  - Impact events
  - Entities with Motion
    - Aircraft, cars, ships, machinery, hand-held drills, engines, valves, etc.
  - Characterization of rough surfaces, peel testing, etc.
  - Material characterizations of advanced materials
- **Quantities**
  - Most noisy – accelerometers
  - Moderate noise – string pots, laser “gauges” (velocity, strain, …), force transducers
- ***Computing the derivative of data can easily create a noisy result***

Other Challenging Data



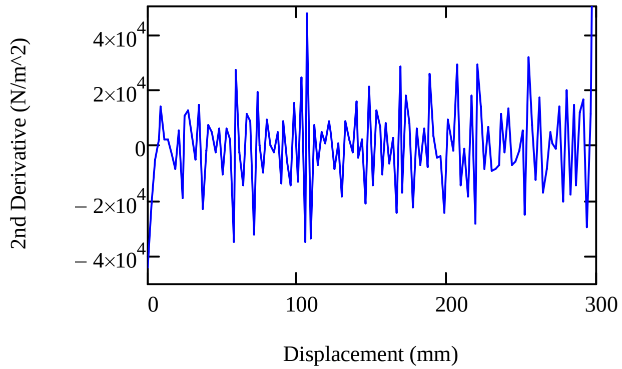
$$\frac{dF}{d\delta}$$

derivative1_k(δraw, Fraw, "")



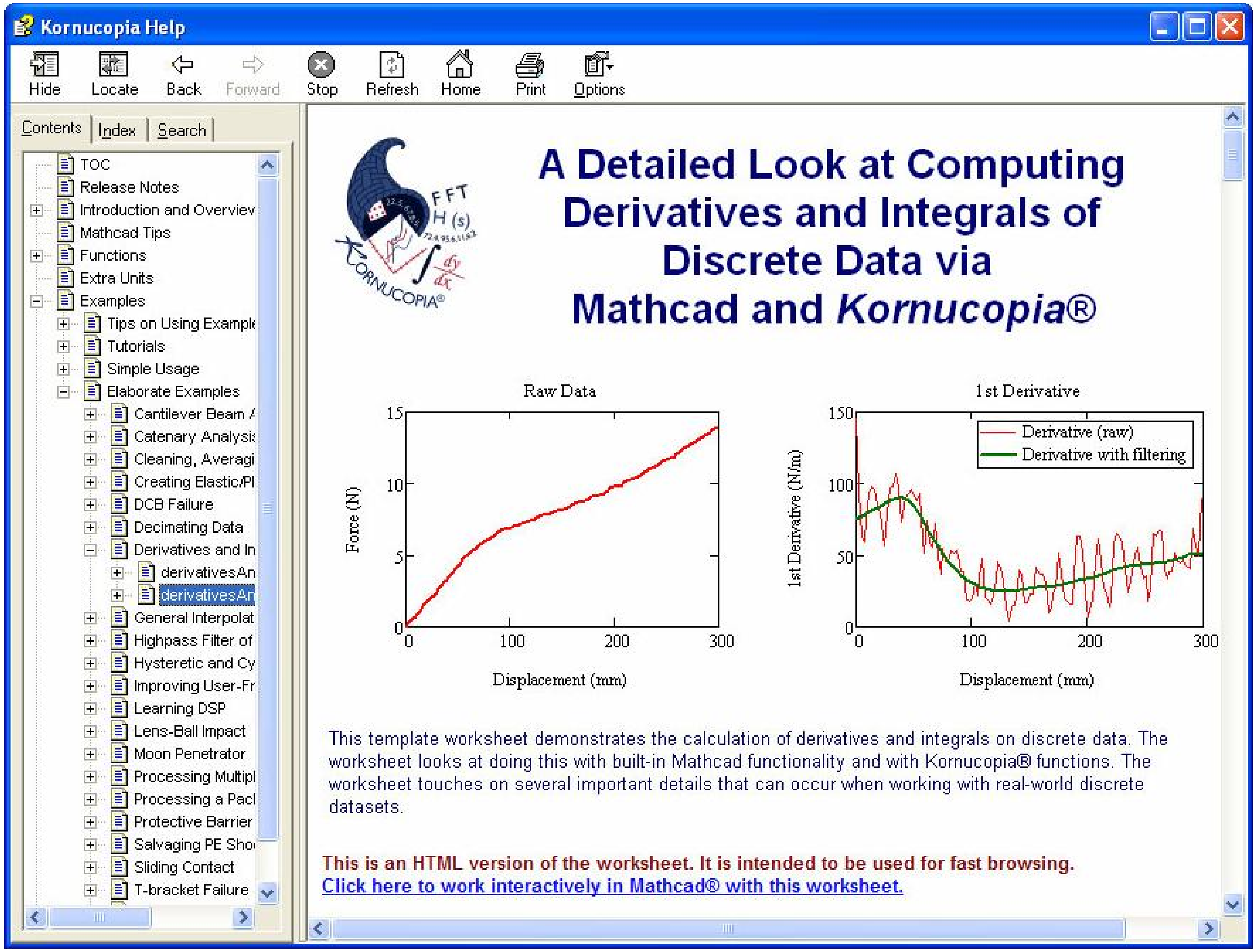
derivative2_k(δraw, Fraw, "")

$$\frac{d^2F}{d\delta^2}$$



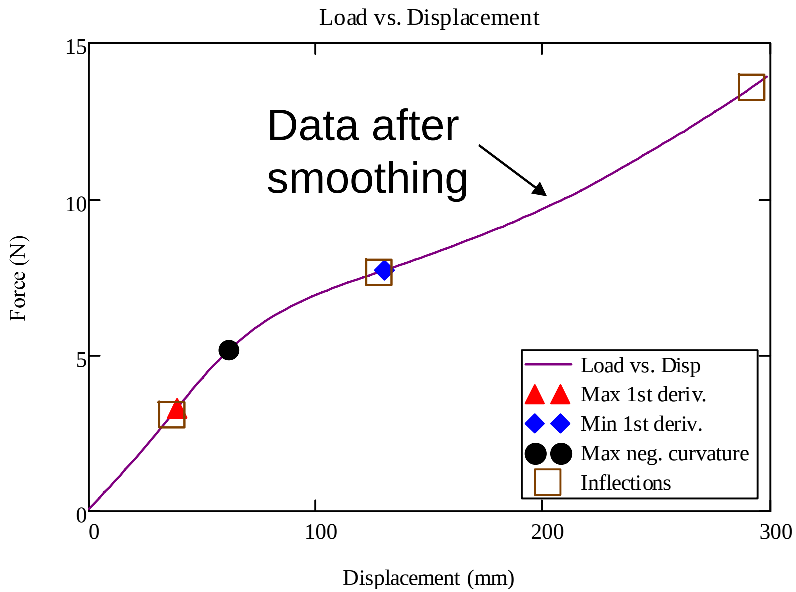
These derivatives looks terrible?
– Can I do anything about it?

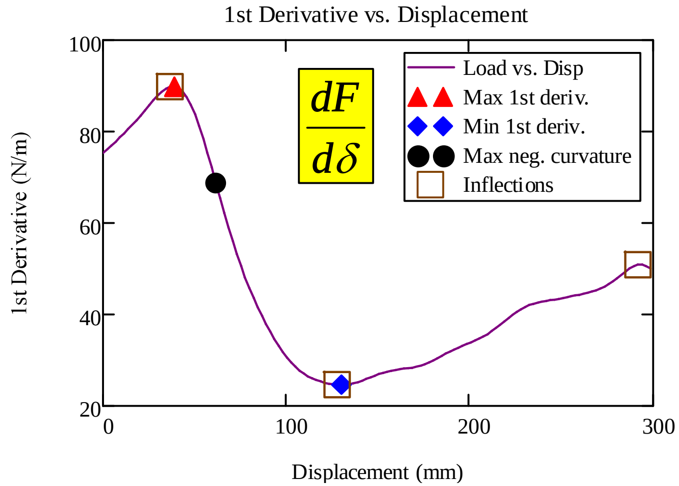
Kornucopia® Help and Templates Provides Guidance

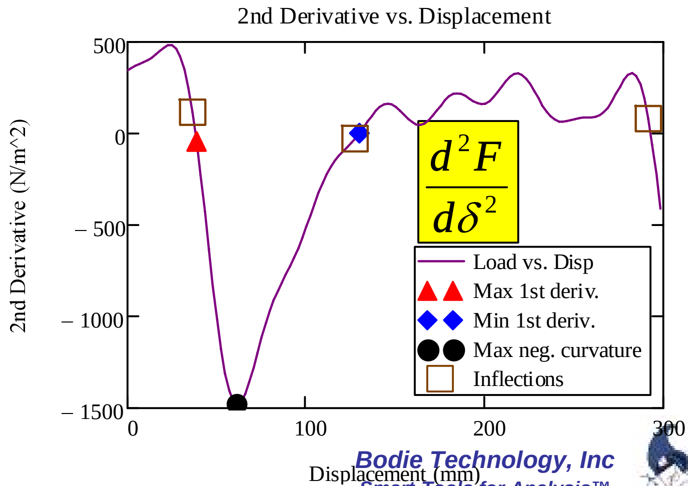


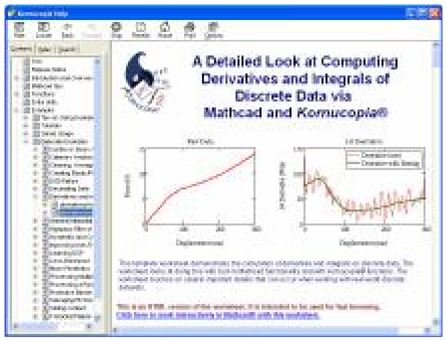
Noisy Derivative Challenge

Kornucopia® Meets the Challenge!





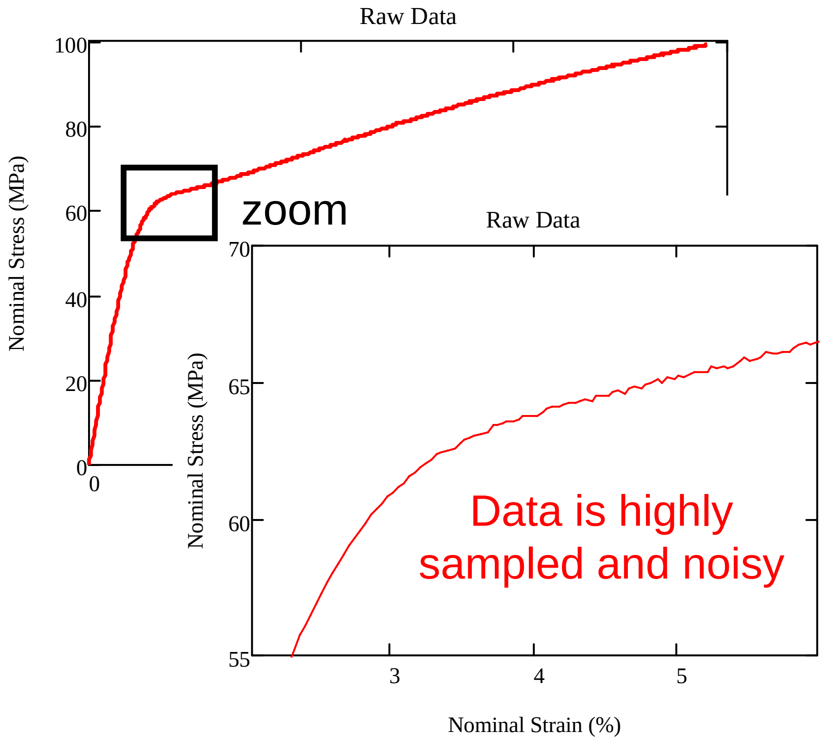




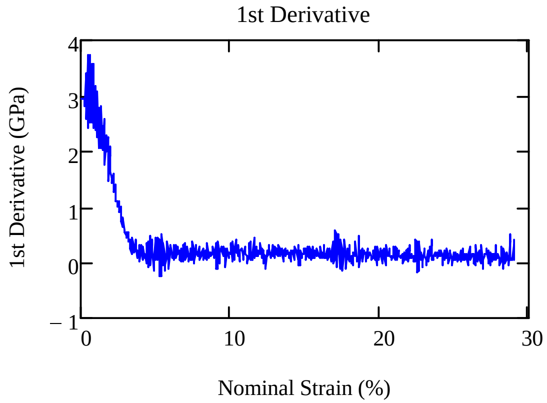
Solution Using Both Filtering & Derivative Functionality in Kornucopia®

Here is a Simple Dataset that Looks Smooth

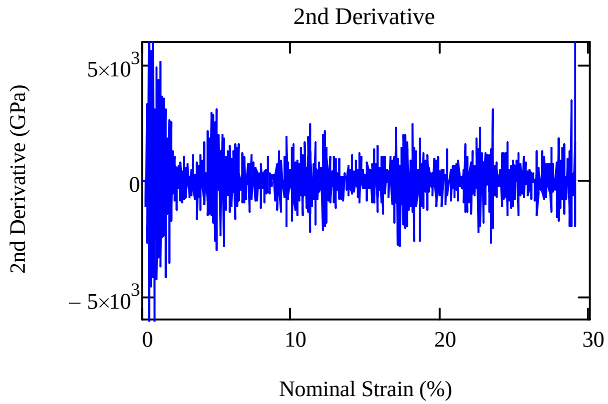
Why do these derivatives looks so noisy?



$$\frac{dT}{d\varepsilon}$$

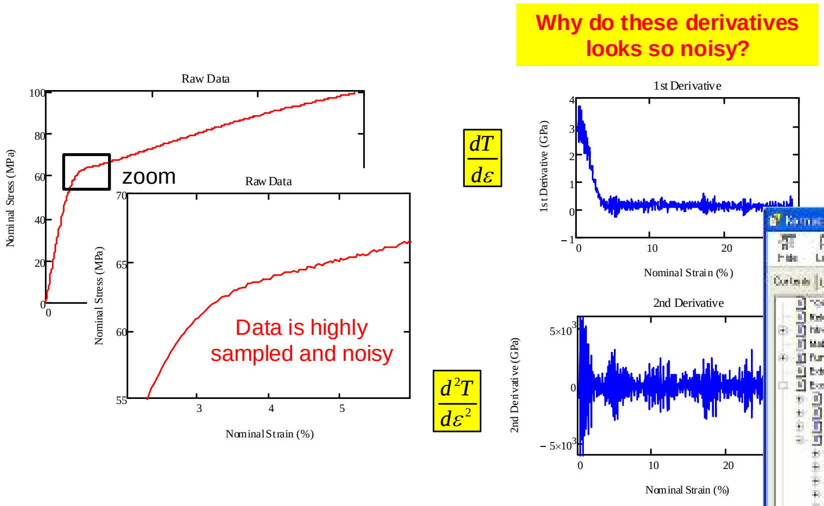


$$\frac{d^2T}{d\varepsilon^2}$$

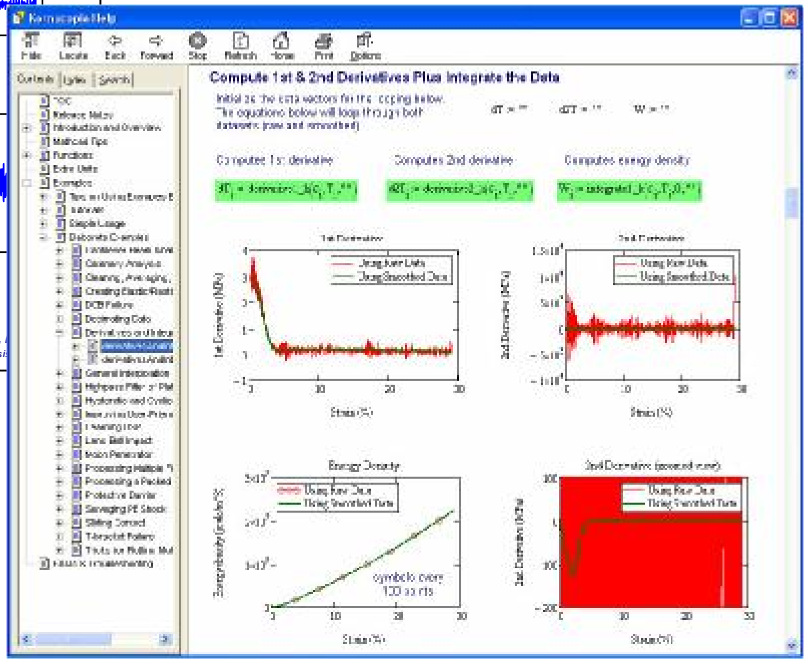


Kornucopia® Library Suggests Suitable Work-Flows

Here is a Simple Dataset that Looks Smooth

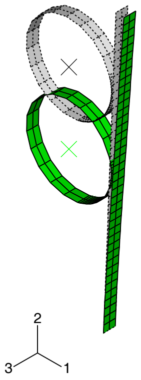


Kornucopia® Example shows solution using both Filtering & Derivative Functionality

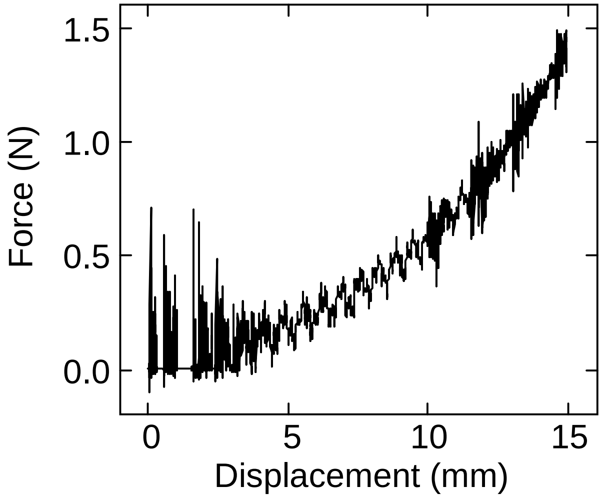


Bodie Technology, Inc
Smart-Tools for Analysis™

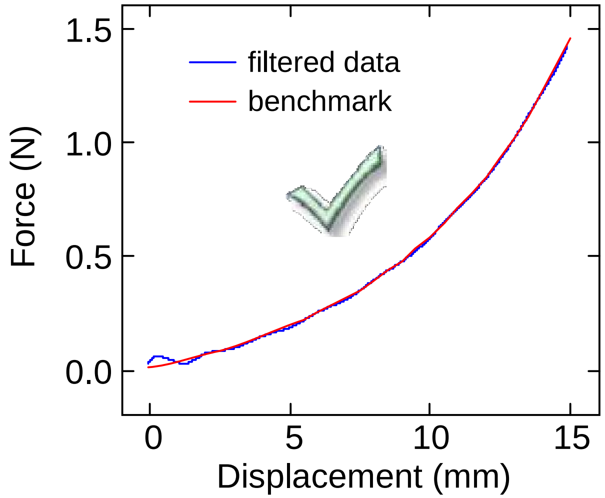
Kornucopia® DSP Technology is Robust



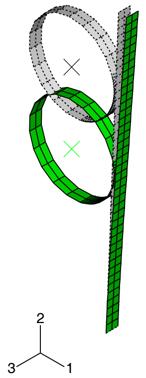
Raw Data



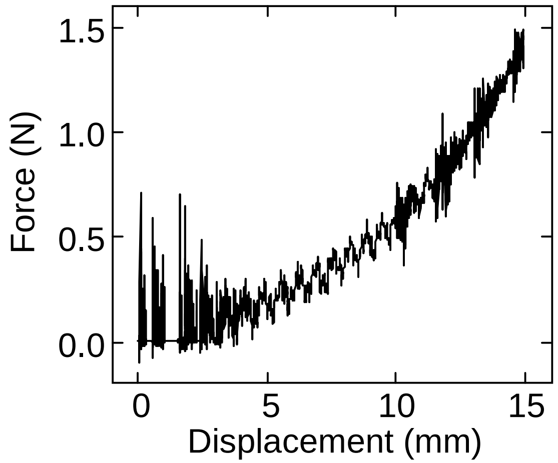
smooth := smoothXY_k(data,99.5%,"")



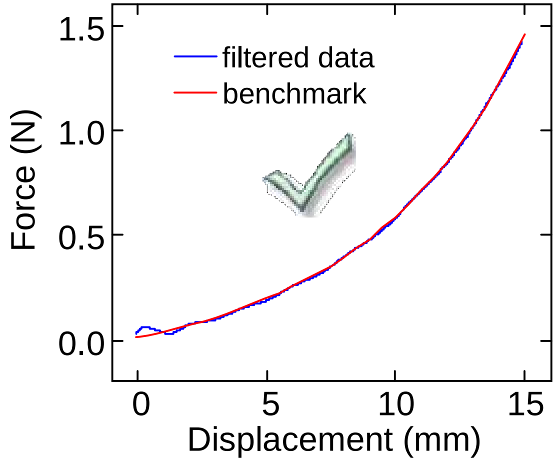
Kornucopia® DSP Technology is Robust



Raw Data

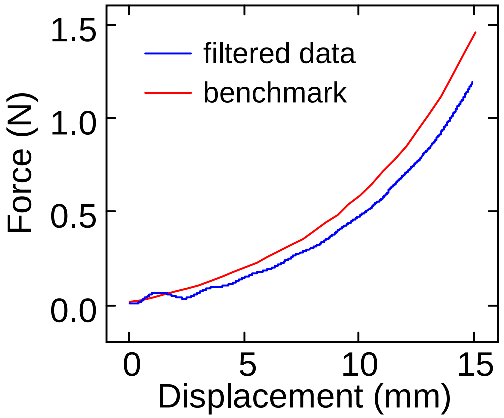


smooth := smoothXY_k(data, 99.5%, "")

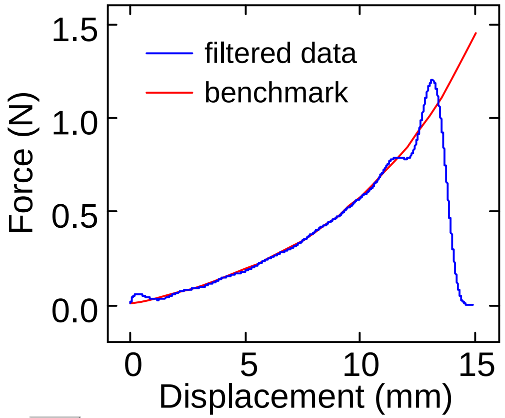


Other DSP Software & Approaches

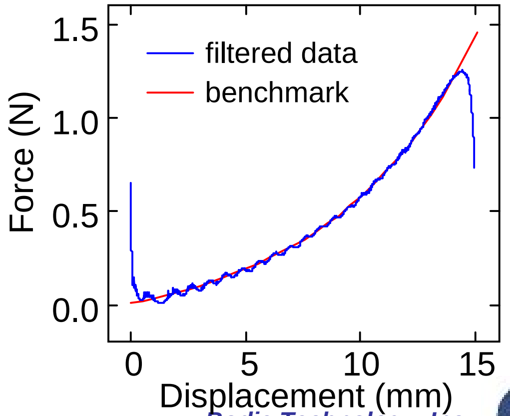
Single pass Butterworth filter



Bi-directional Butterworth filter



FFT filter



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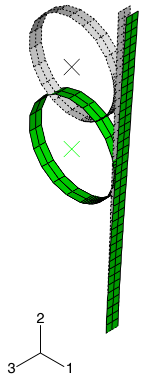
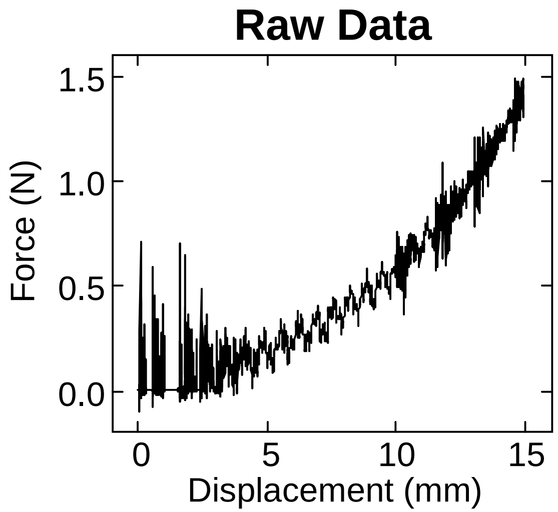
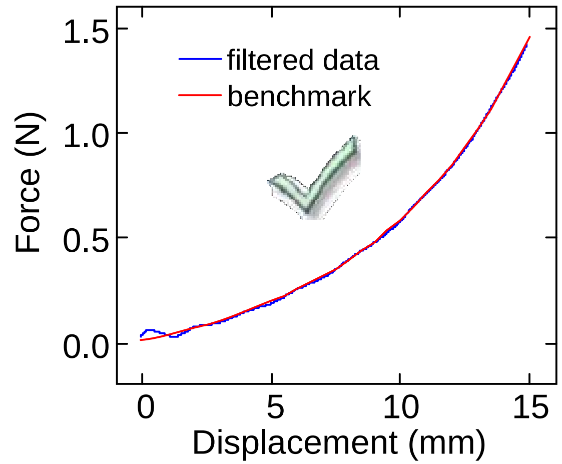
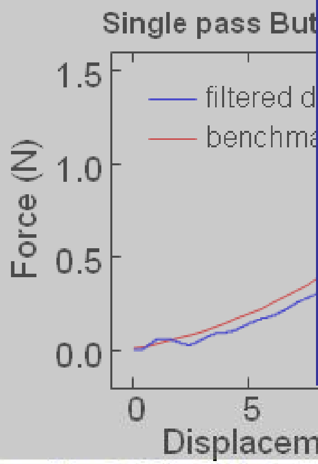
Kornucopia® DSP Technology is Robust

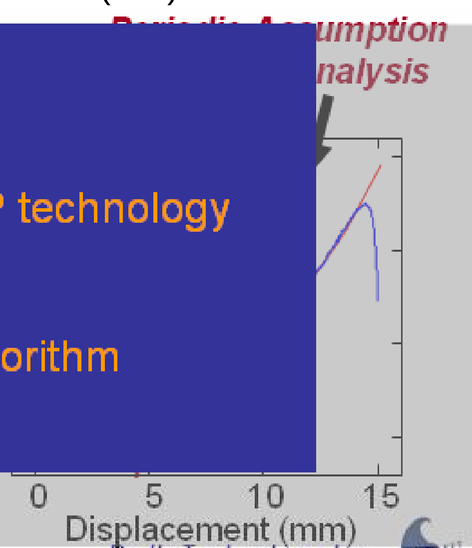




smooth := smoothXY_k(data, 99.5%, "")





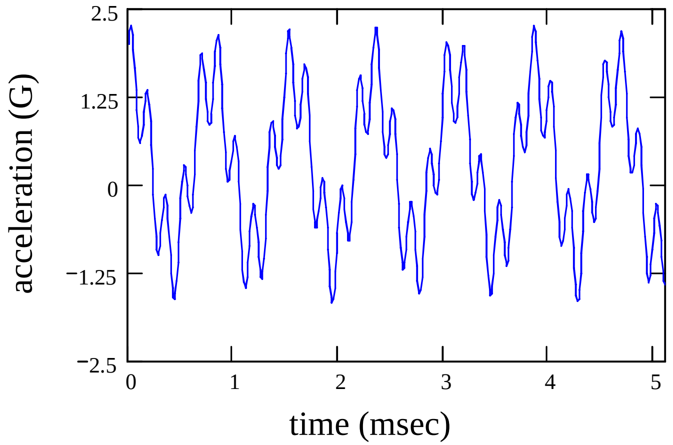


smoothXY_k

- Works well over a broad range of data
- Uses Kornucopia® Smart-Function™ DSP technology
  - ✓ Bi-directional Butterworth filter
  - ✓ Automatic end-effect minimization algorithm
  - ✓ User-friendly input parameters

Time-Domain and Frequency-Domain – “FFT” Example

Time-domain



$$A(t) = a_{DC} + a_1 \sin(2\pi f_1 t + \phi_1) + a_2 \sin(2\pi f_2 t + \phi_2)$$

Analytical frequency content	
Freq (kHz)	**Amplitude (G)**
0.0	**0.3**
1.3	**1.27**
6.0	**0.7**

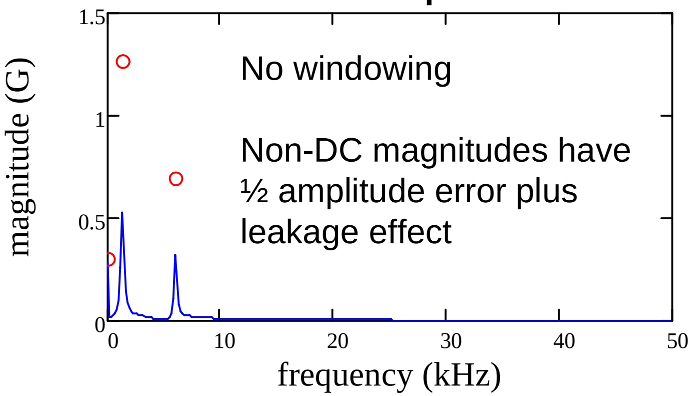
- **MEscope**, Version 4.0.0.69, released 10/17/2005.
  - “FFT” calculated using a rectangular window and the menu commands of `Transform, FFT.`
- **MATLAB® R2006a**, Version 7.2.0.232.
  - “FFT” calculated via `plot(abs(fft(A)))` where A is the time-domain amplitude vector.
- **DASYLab®**, V7.00.03, released 1/28/2003.
  - “FFT” calculated using a rectangular & hanning window and requesting a real FFT of real data via `Signal Analysis, FFT, Amplitude Spectrum`.
- **Kornucopia®**, V1.4, released June, 2009.
  - “FFT” calculated using a rectangular & hann window via the following commands

$m_{noWin} :=$ fourierMag_k(A, boxcar_k, "") $m_{hann} :=$ fourierMag_k(A, hann_k, "")

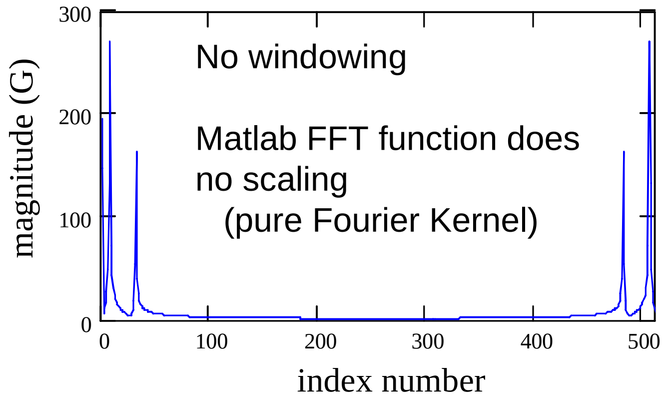
Time-Domain and Frequency-Domain - “FFT” Example

Analytical frequency content	
Freq (kHz)	Amplitude (G)
0.0	0.3
1.3	1.27
6.0	0.7

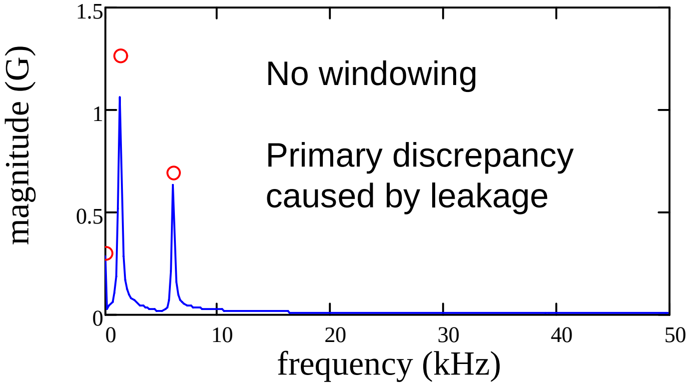
MEscope



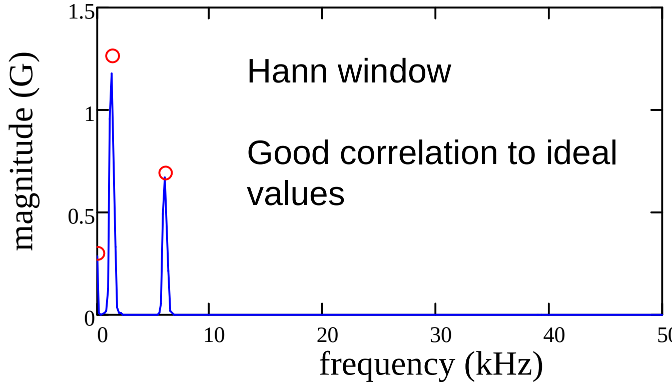
MATLAB®



Kornucopia® & DASYLab®



Kornucopia® & DASYLab®

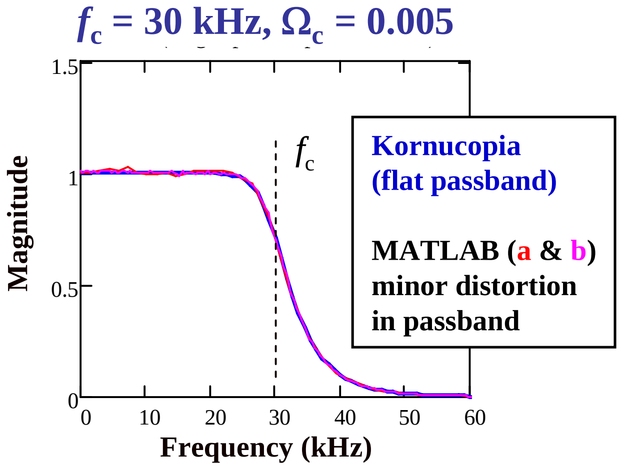


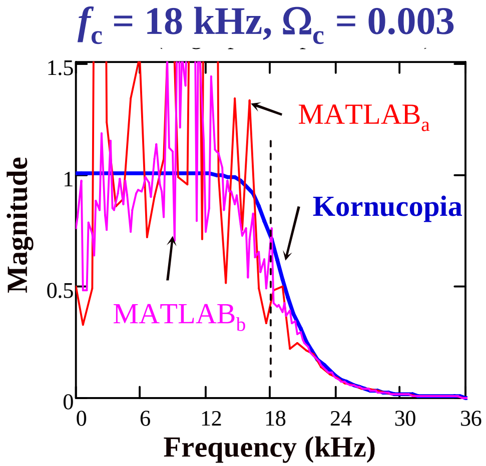
Working with Highly Over-Sampled Data

- **MATLAB®'s Signal Processing toolbox versus Kornucopia®**
  - The analysis is based on results initially published by: Diehl, T., et. al., "Applications of DSP to Explicit Dynamic FEA Simulations of Elastically-Dominated Impact Problems," *Journal of Shock and Vibration*, Vol 7, 2000, pp. 167-177.
    - Note: The MATLAB® results have been updated in 2007 and the Kornucopia® results were added in 2007.
- The evaluation examines performance of the two DSP software packages when data is highly over-sampled and a relatively aggressive filter is applied.
  - f_s = 6 MHz Sampling Rate.
  - 8th-order Butterworth Lowpass Filter
  - Values for typical for explicit-dynamics models and filters potentially applied by a "non-DSP" FEA user.

Working with Highly Over-Sampled Data

- FRF Evaluations
  - FRF shows how filter will attenuate frequency content of signal





MATLAB®' has difficulty as normalized cutoff frequency is lowered.

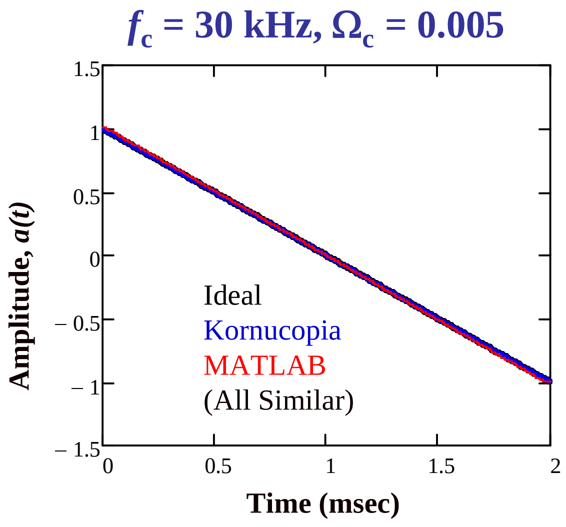
Ω_c is the normalized cutoff frequency (f_c/f_s). f_s = 6 MHz (all cases)

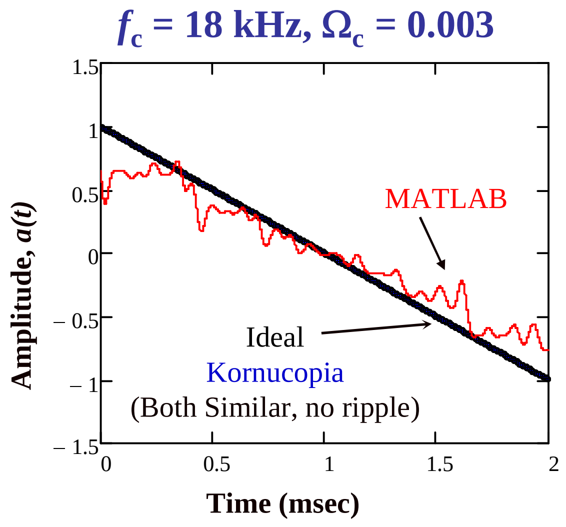
Kornucopia® - Used function FRFmag_k(C, Ωplot, "delay compensation : 0")
MATLAB$_a$ - Used FFT-based algorithm via the MATLAB® command [h,f] = freqz(b,a,n,Fs)
MATLAB$_b$ - Used algorithm based on Horner's polynomial eval. via the MATLAB® command [h,f] = freqz(b,a,f,Fs)

Working with Highly Over-Sampled Data

Time-domain results of filtering a **sloped line**.

- The MATLAB® filter function utilized was `filtfilt`, a bi-directional time-domain filter. This function does NOT use a cascaded filter implementation.
- The lowpass filter utilized by Kornucopia® was `filterY_k`, a bi-directional time-domain filter, implemented in a cascade form.
- MATLAB® becomes unstable with small change in cutoff frequency.



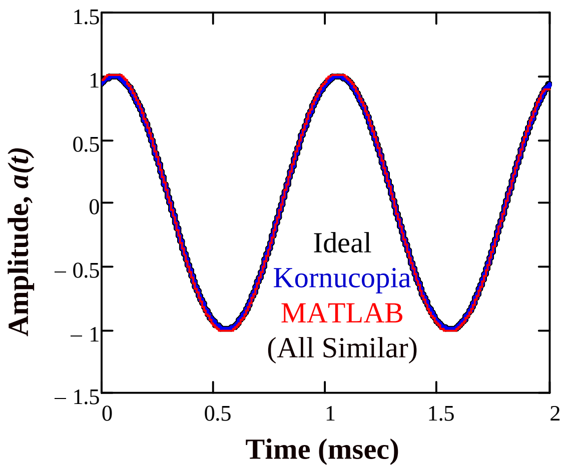


Working with Highly Over-Sampled Data

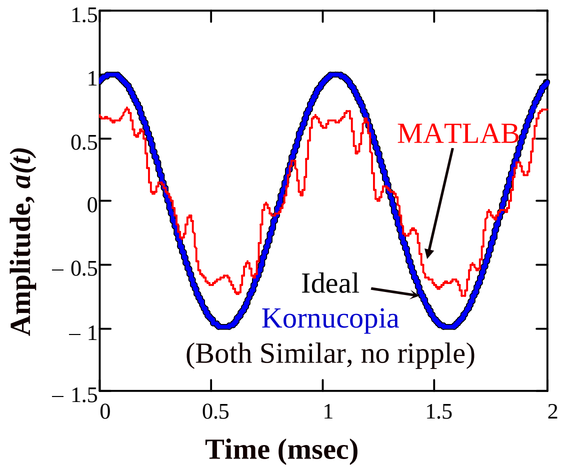
Time-domain results of filtering a simple **1.0·kHz sinusoidal signal**.

- Since the cutoff frequencies are well above the signal's frequency content, the filtered result should yield back the original 1.0·kHz sine wave.
- The MATLAB® and Kornucopia® filter functions are same as before.
- Similarly poor results occur again with MATLAB®.

f_c = 30 kHz, Ω_c = 0.005



f_c = 18 kHz, Ω_c = 0.003



Enhancing Material Characterization from Raw Data

Basic Steps for Elastic/Plastic Data

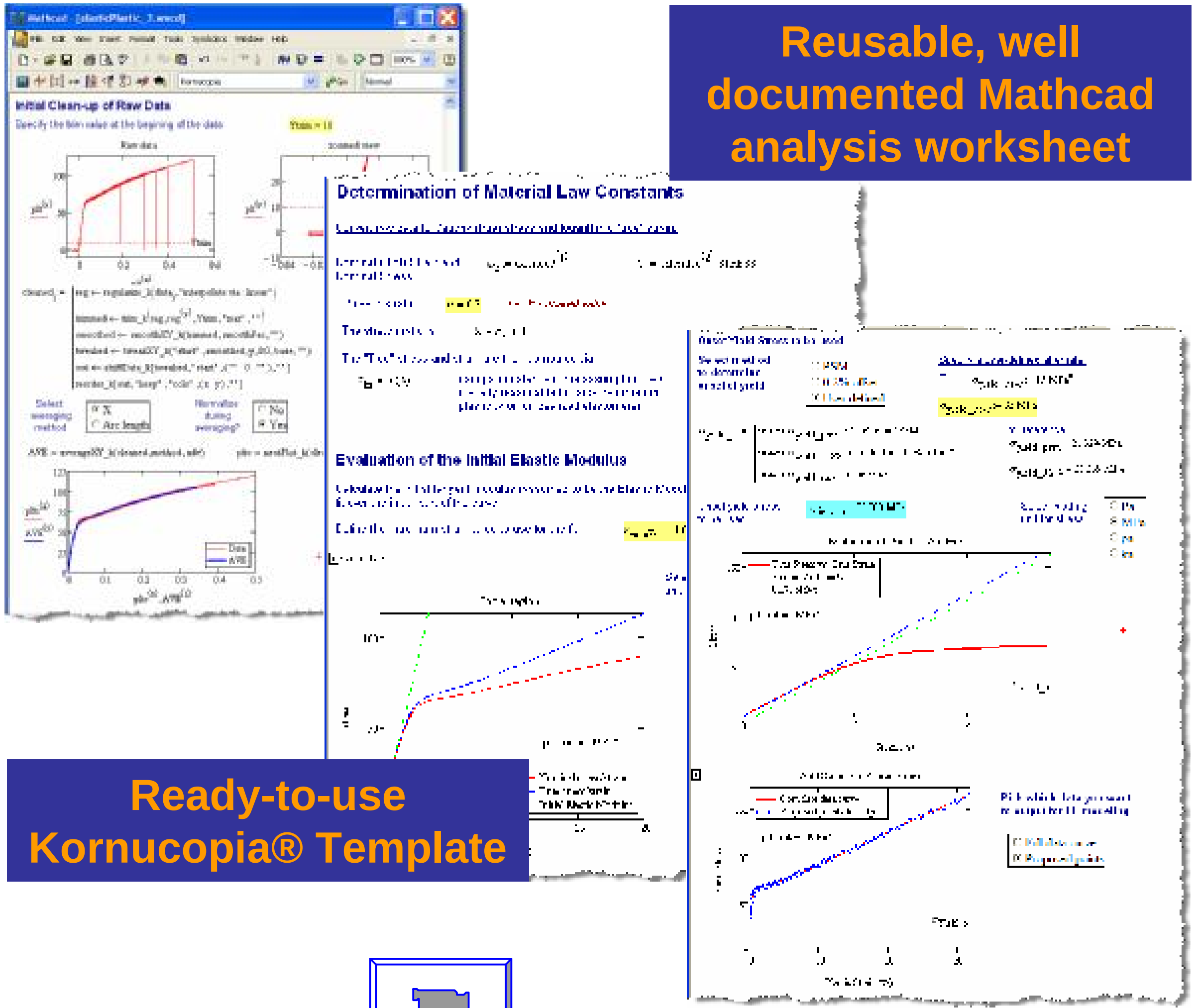
A. Clean and average raw data

B. Convert nominal stress/strain to true stress/strain

C. Determine modulus

D. Obtain yield stress vs plastic strain curve

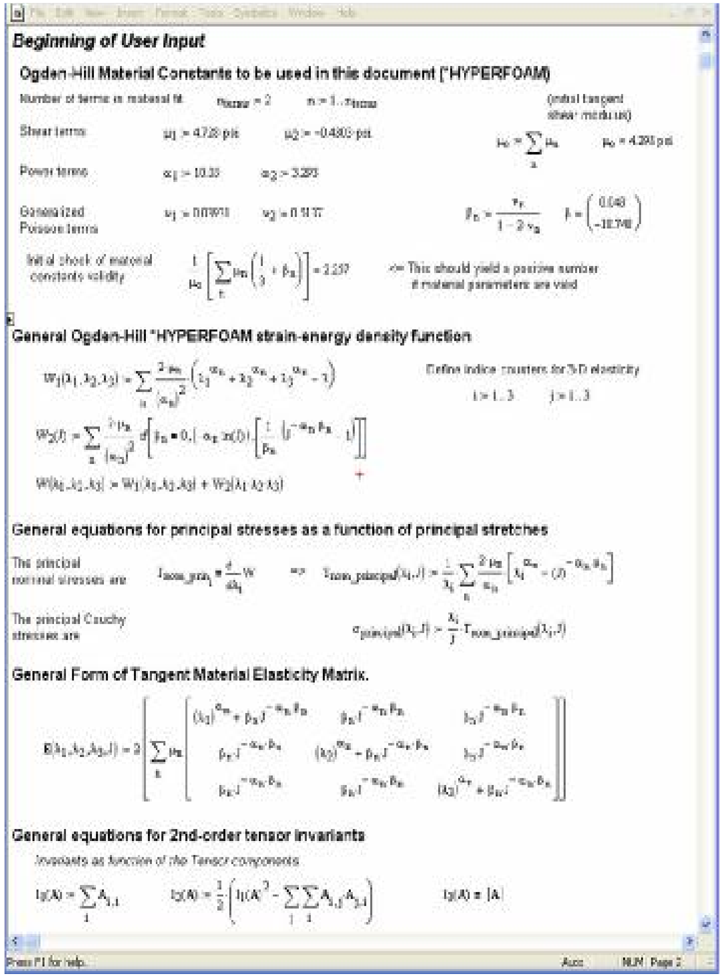
E. Output to ASCII file for FEA or other use

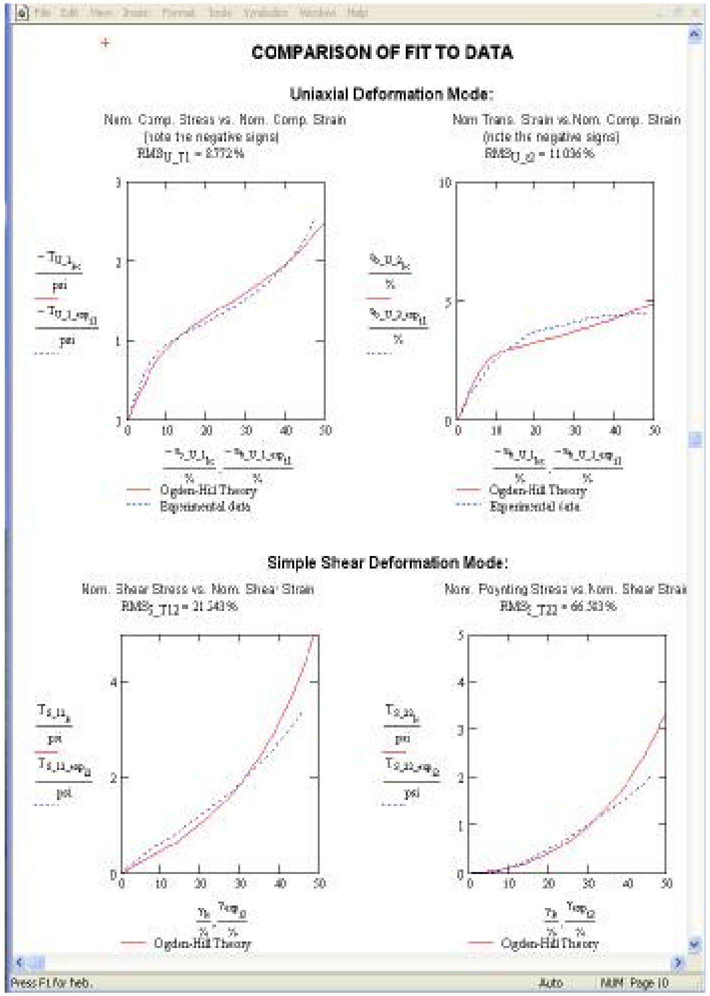


Reusable, well documented Mathcad analysis worksheet

Ready-to-use Kornucopia® Template

Improving the Fit of Test Data to Hyperfoam Model

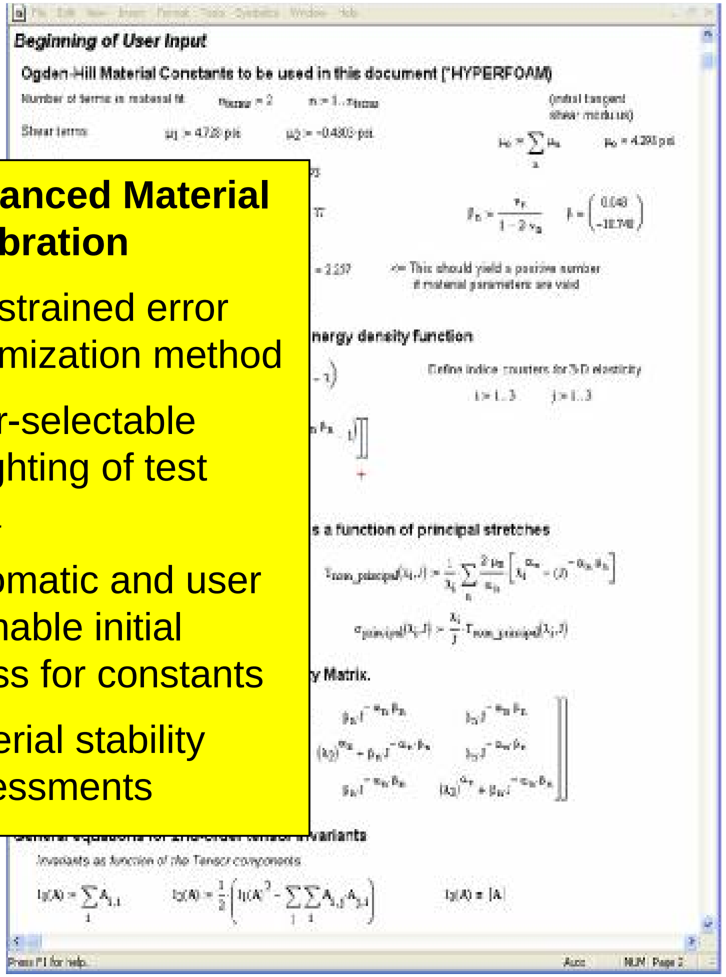


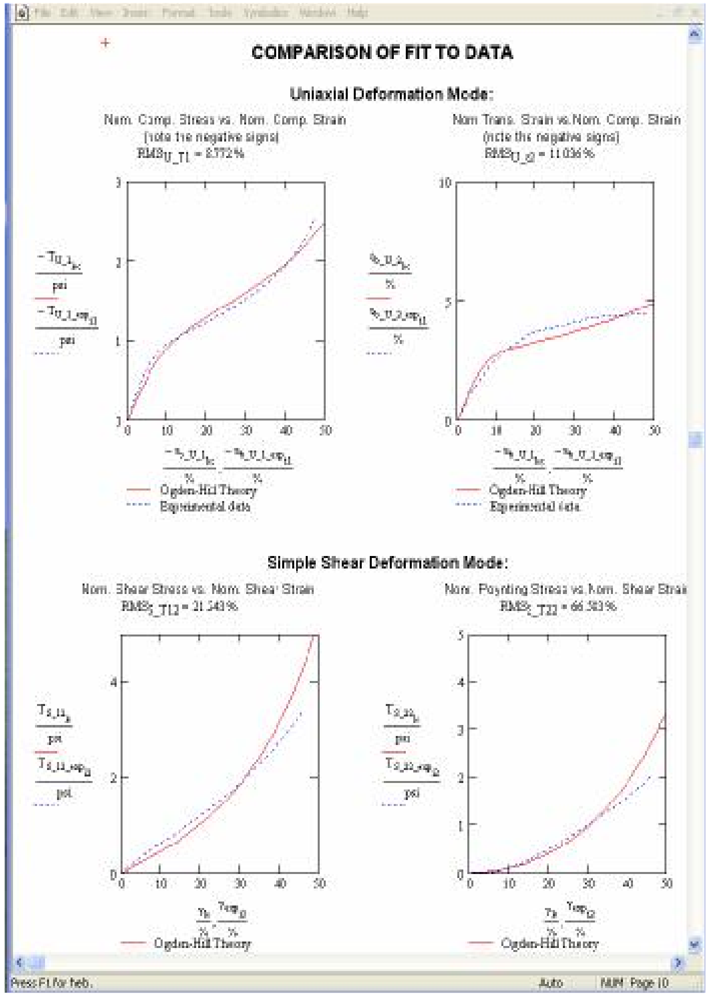


Improving the Fit of Test Data to Hyperfoam Model

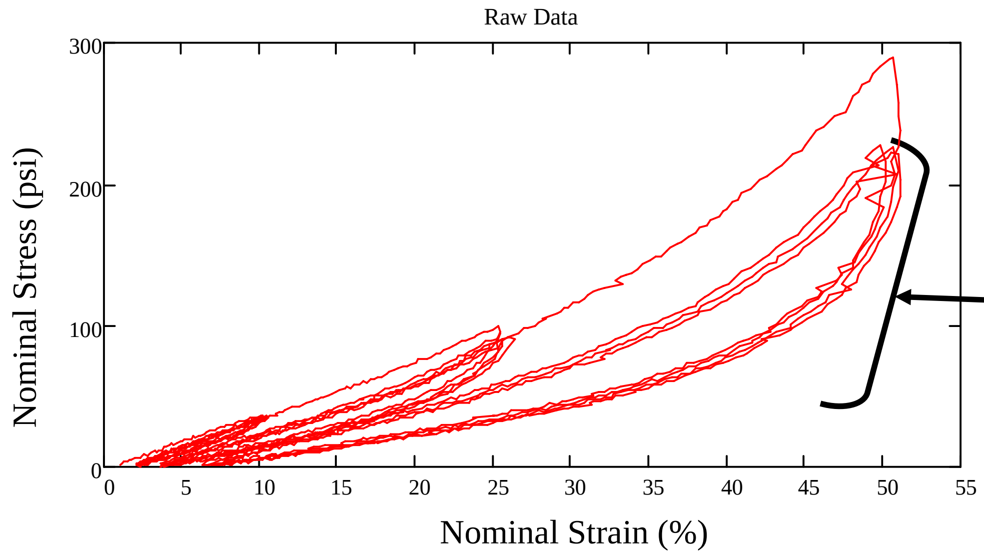
Advanced Material Calibration

- Constrained error minimization method
- User-selectable weighting of test data
- Automatic and user definable initial guess for constants
- Material stability assessments



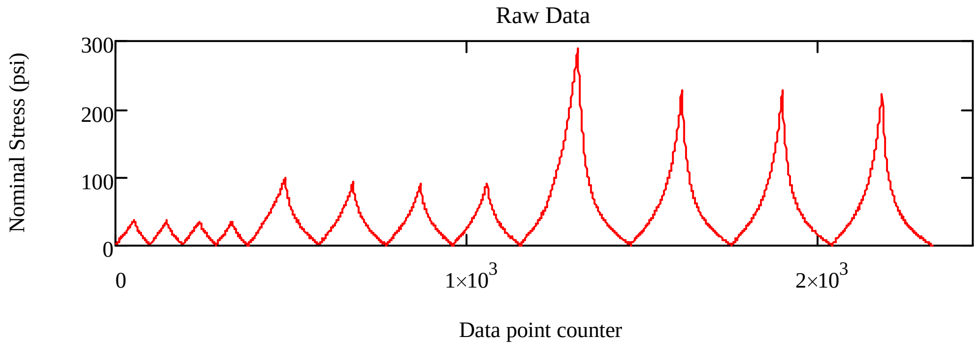


Hysteresis Test Data – Often a Real Headache



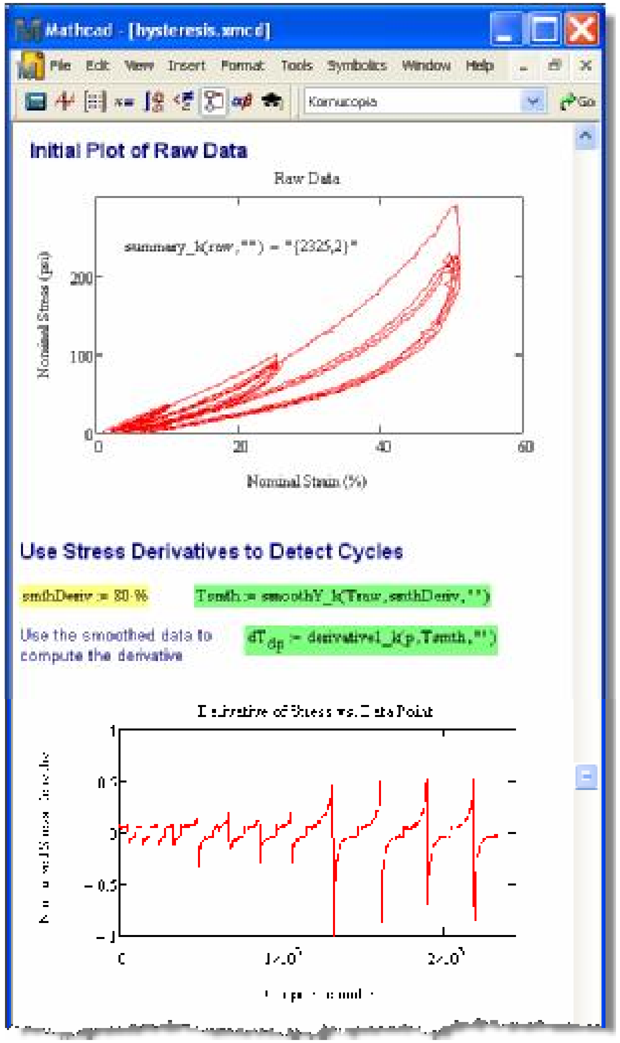
Reciprocating process equipment data has similar issues

Problem caused by noise in optical strain measurement using a laser sensor

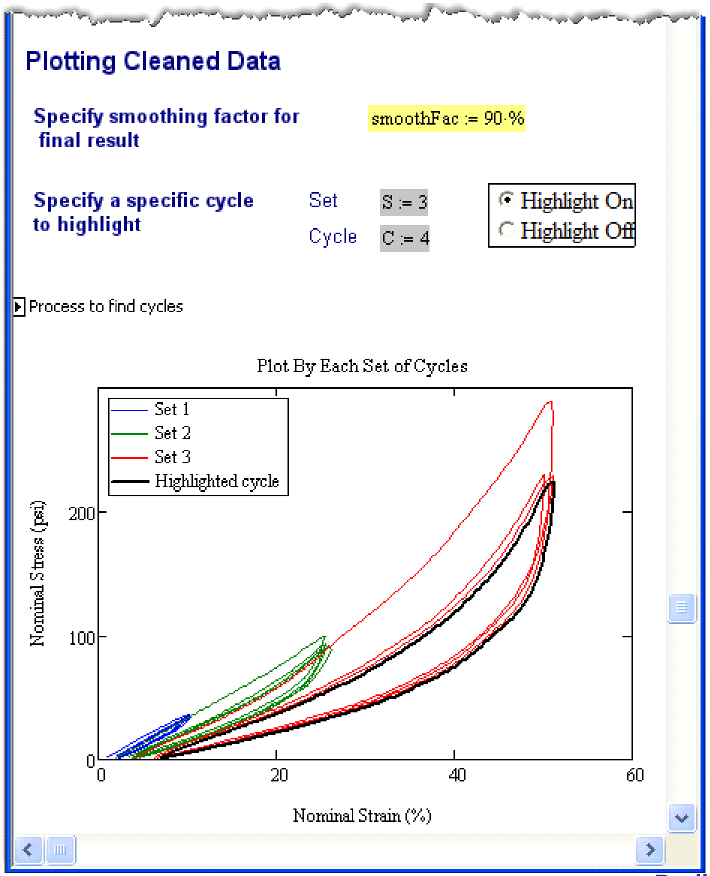


Can we use derivatives of stress or strain to automatically separate each cycle (loop)?

Another Ready-Made Solution in the Kornucopia® Library



Kornucopia® Meets the Challenge!

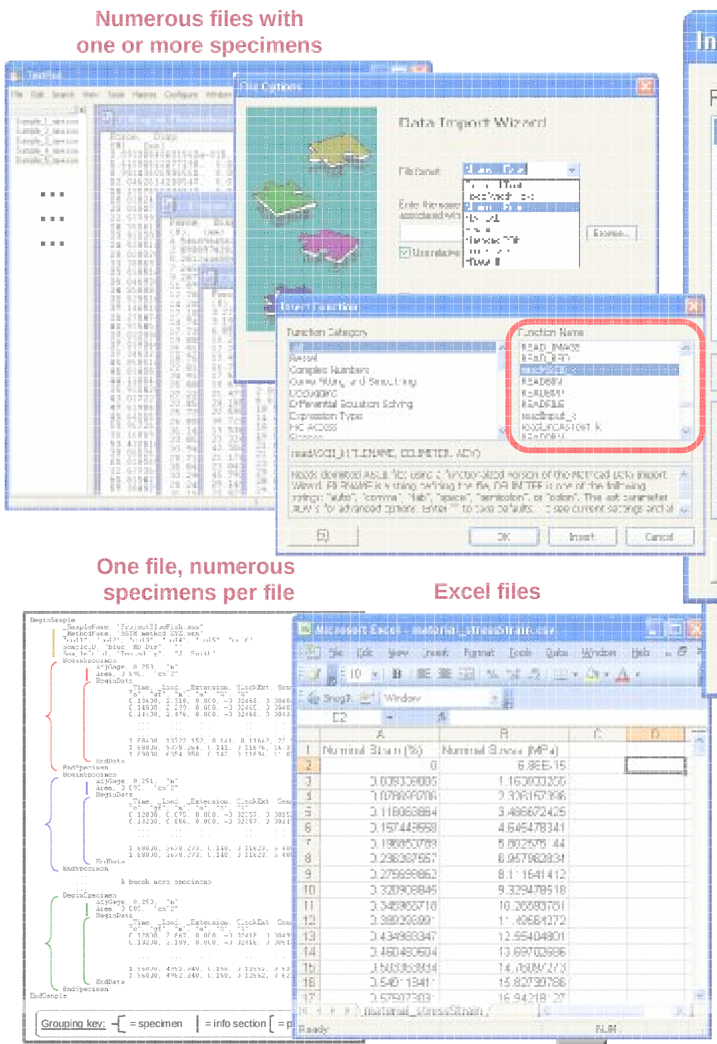


Solution

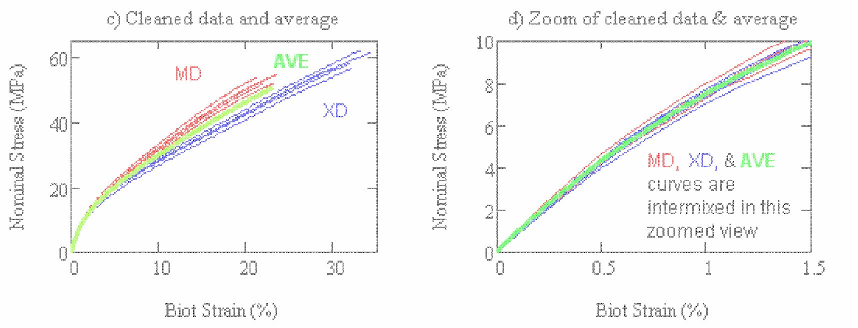
Ready-made template that uses:

- DSP smoothing
- Derivatives
- Index searching
- Programming

Kornucopia Improves Work-Flows That Use Data



- Powerful, easy-to-use functionality
- Logical work-flows
- Efficiently process data files
  - ASCII, Excel, …
  - Eliminates wasteful hand-editing of files
  - Keep header text with your data!
    - ✓ Improve data integrity
  - Single file or many files



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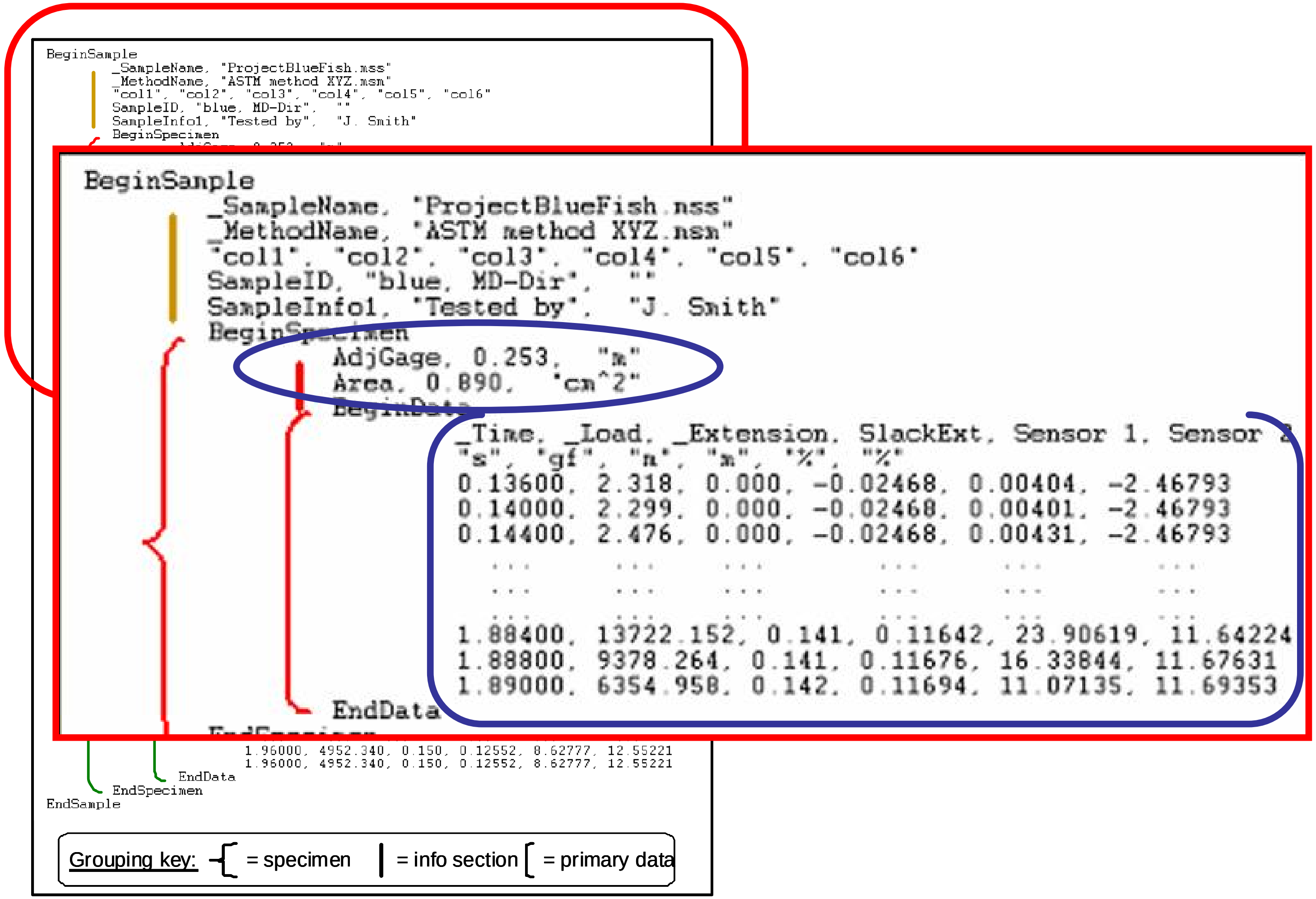
Smart-Tools for Analysis™

Kornucopia® Readily Handles Numerical Data and Text



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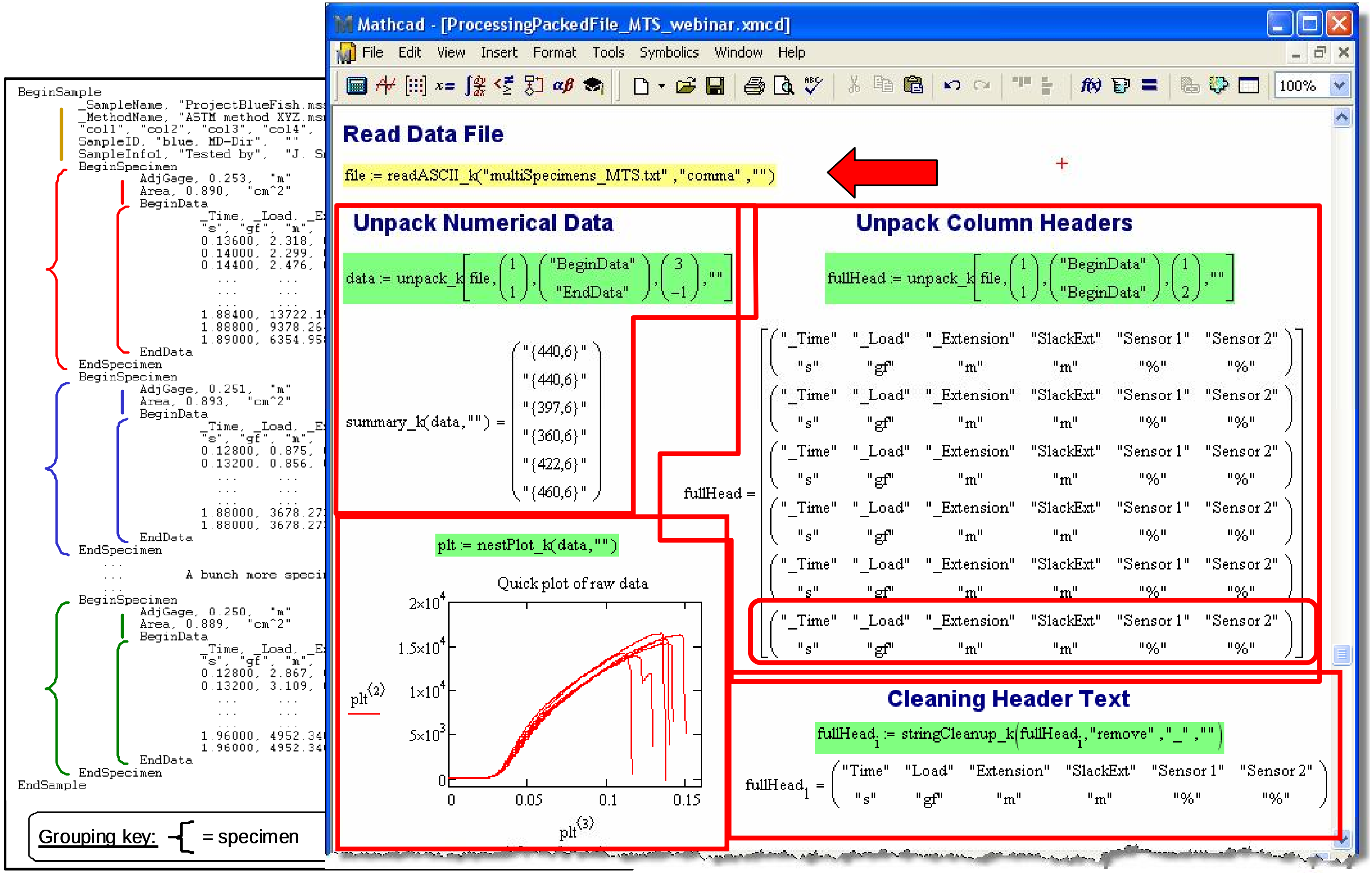
Kornucopia Readily Handles Numerical Data and Text



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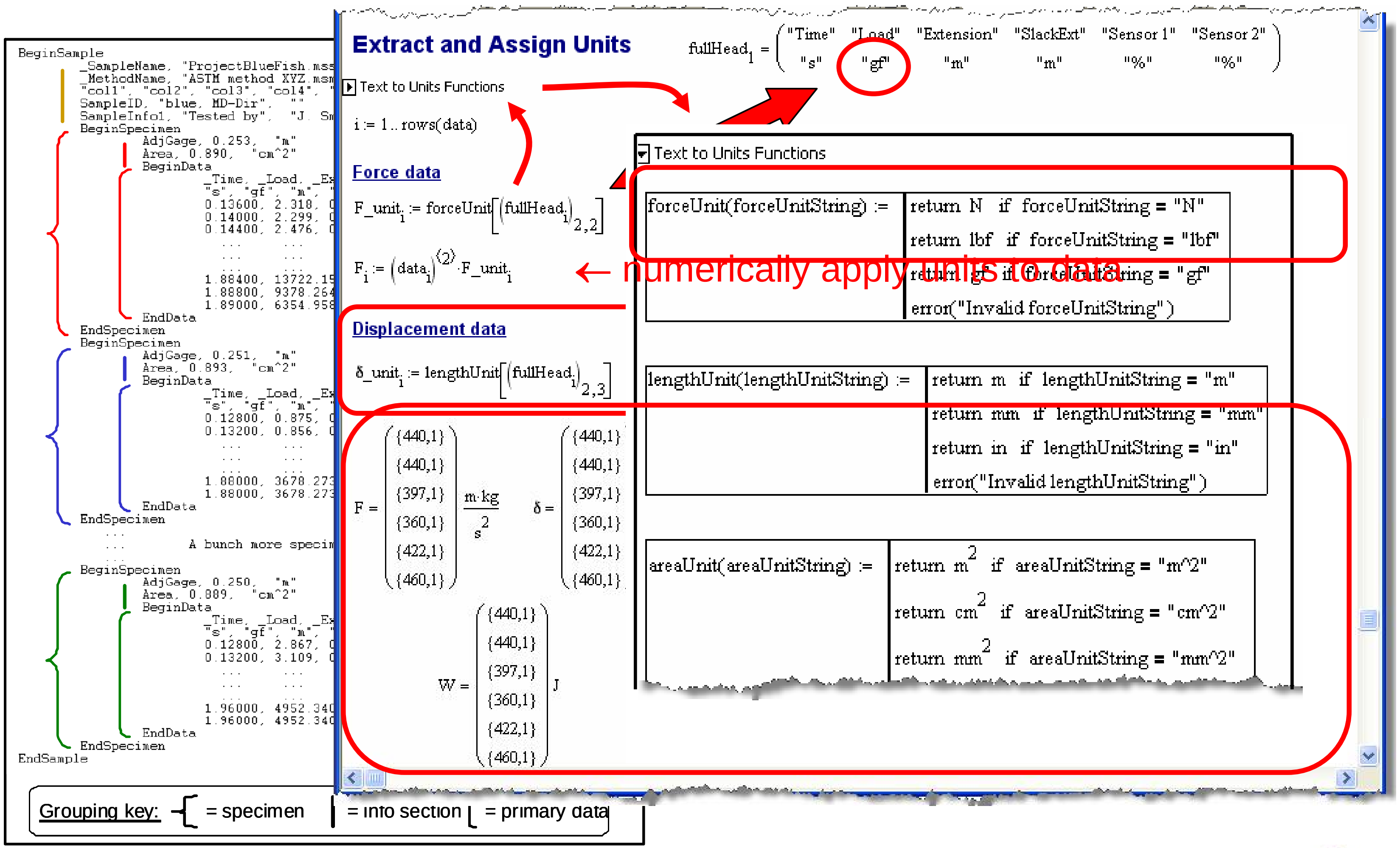
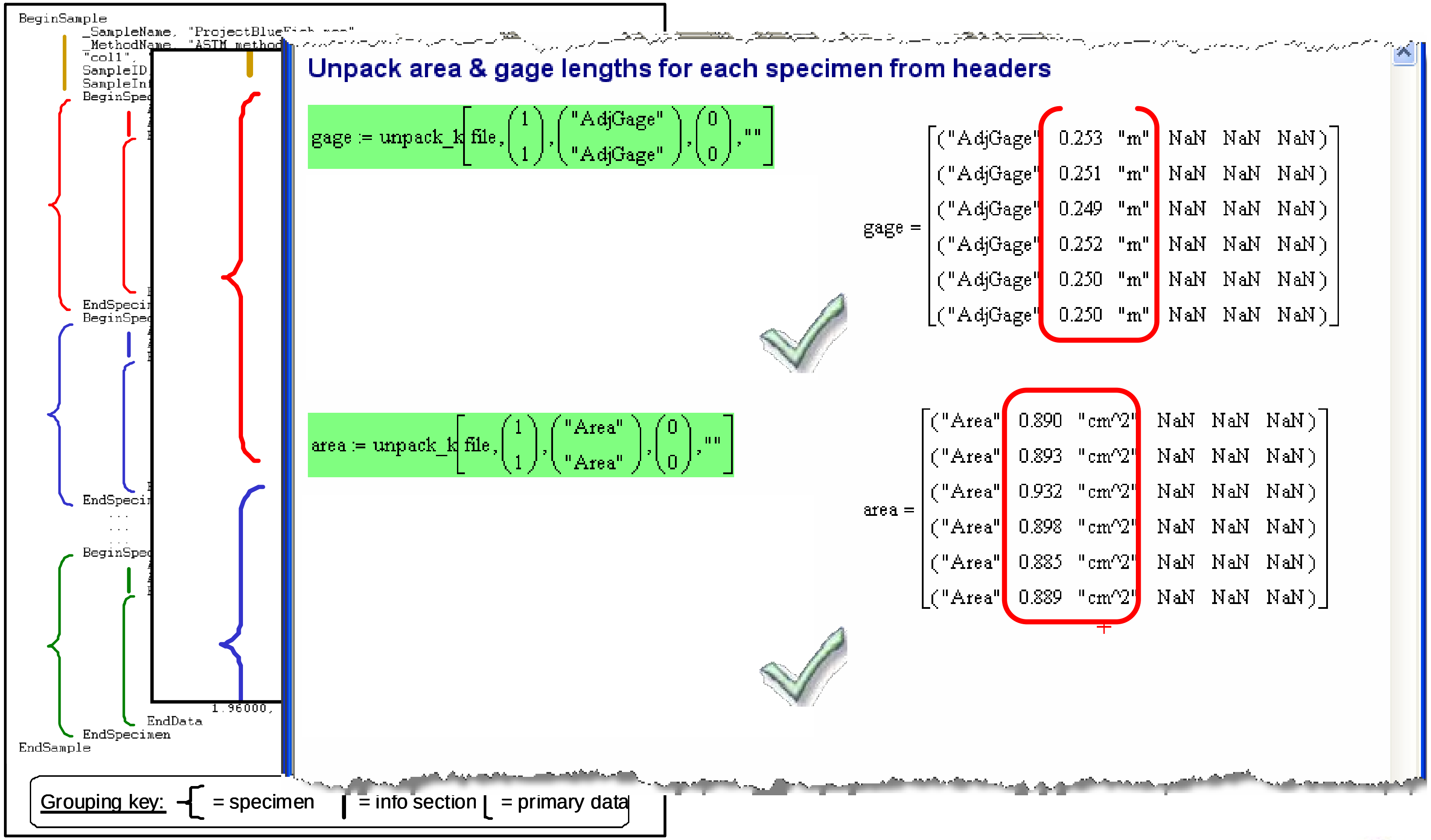
Kornucopia Readily Handles Numerical Data and Text



Kornucopia Readily Handles Numerical Data and Text



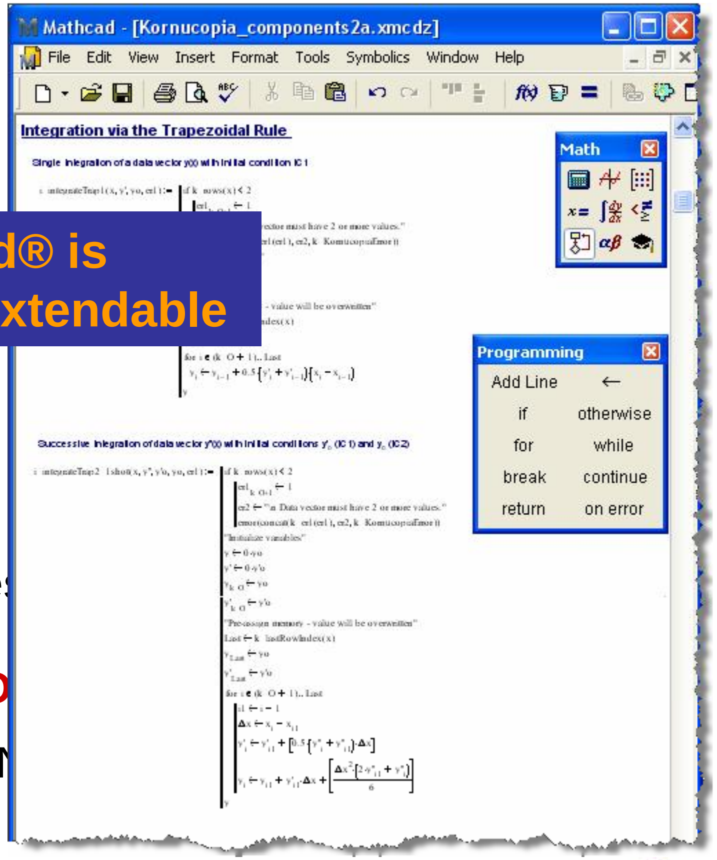
Bodie Technology, Inc
Smart-Tools for Analysis™

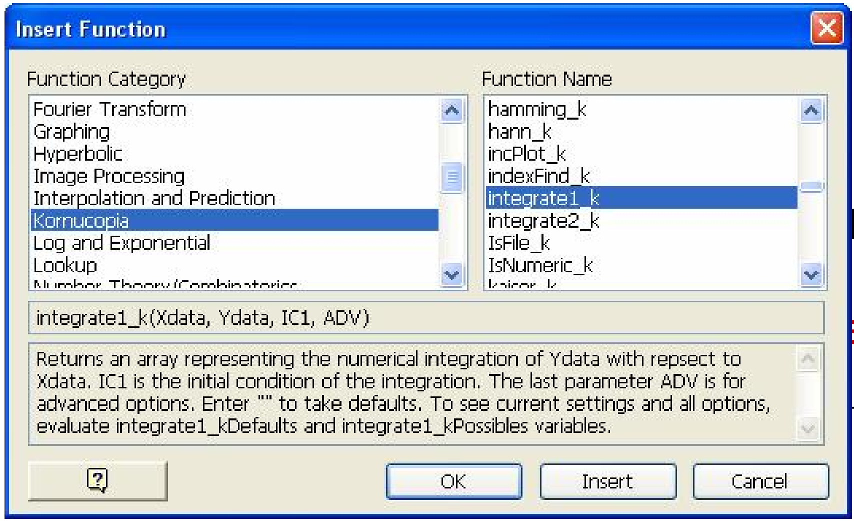
Power of Mathcad® + Kornucopia®

Kornucopia® is Built <u>With</u> Mathcad® <u>For</u> Engineers & Researchers

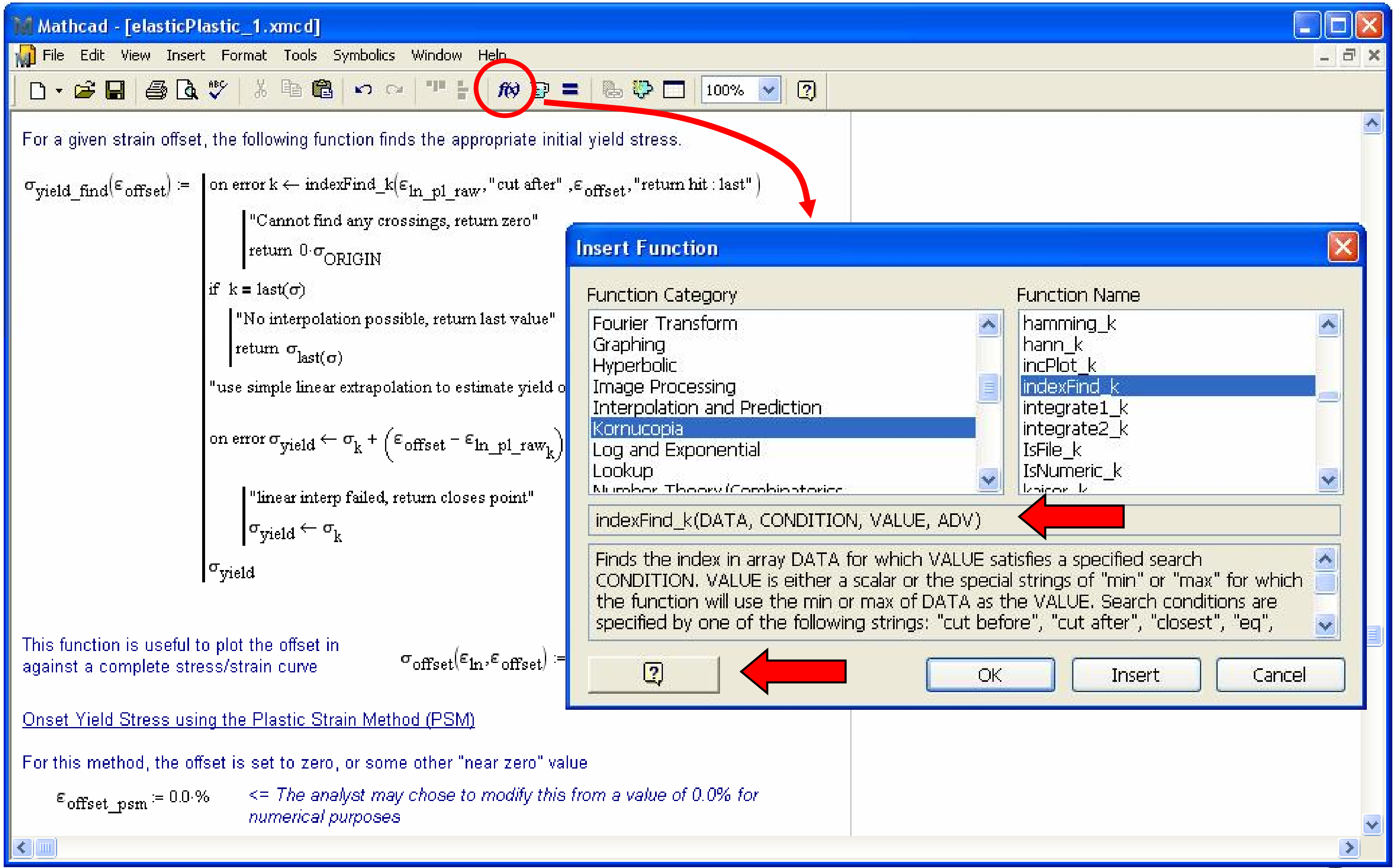
- Written by an Engineer who has used Mathcad for 20+ years
- Mathcad features used:
  - "Smart" referenced worksheets
    - Collapsed, lockable areas
  - Programming (~98%)
  - "C" user DLL's (~2%)

Mathcad® is Powerful & Extendable





Learning About & Accessing Kornucopia® Functions is Easy



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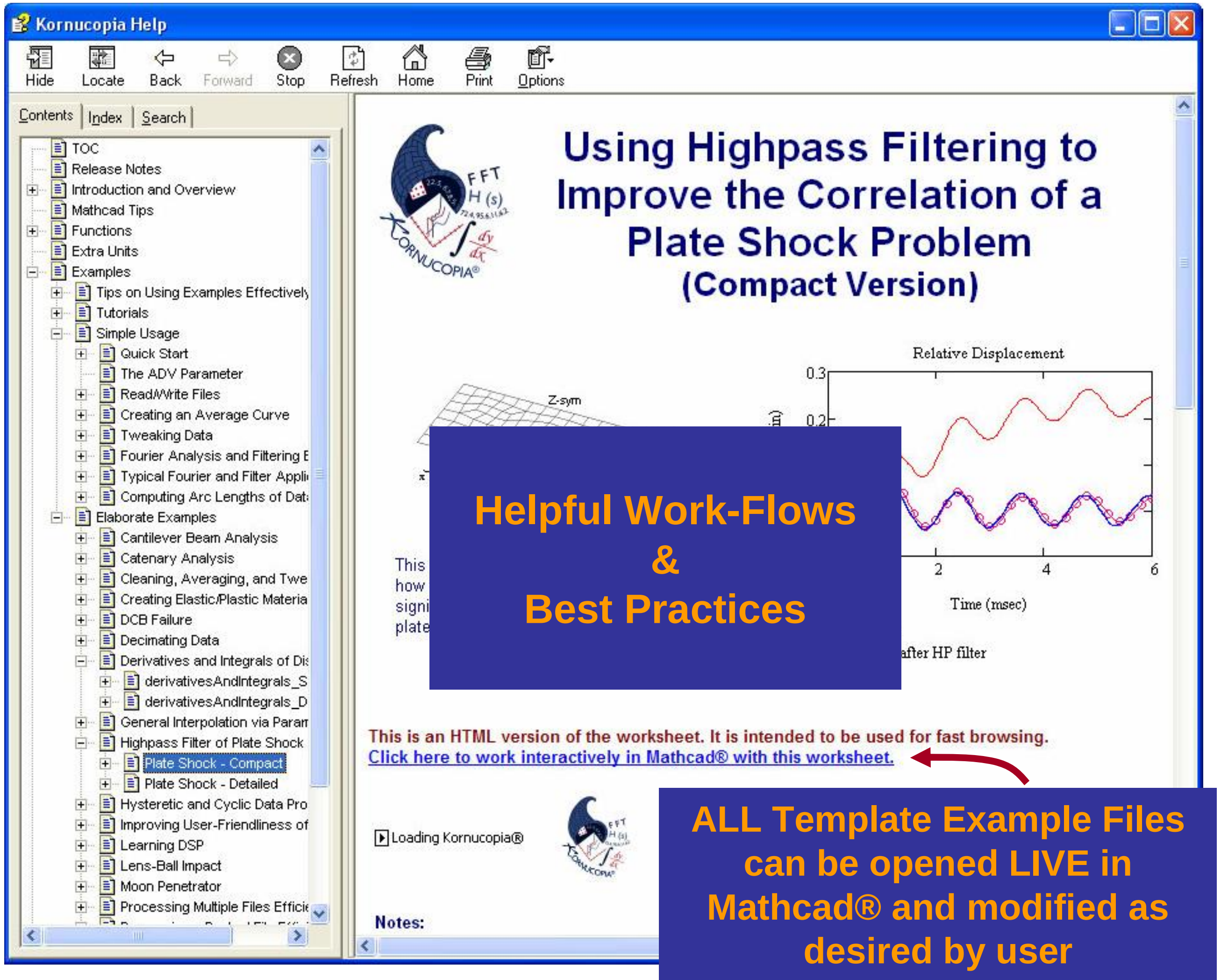
A Rich Library of Example Documents and Templates

Over 30 examples showing how to process a variety of challenging, realistic, datasets



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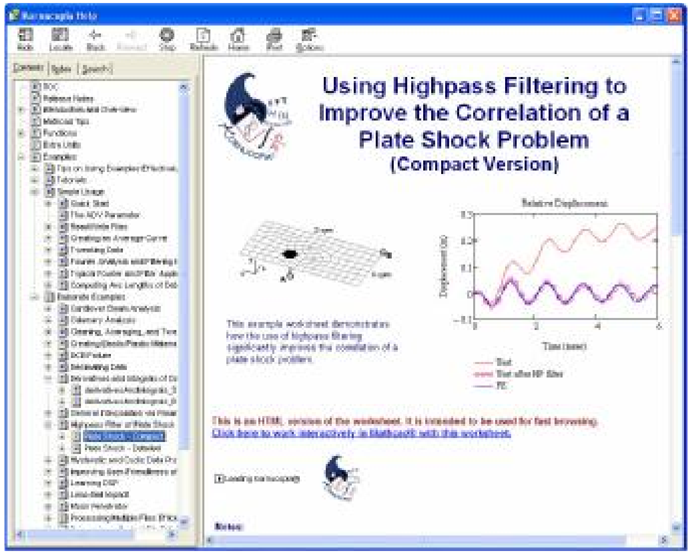
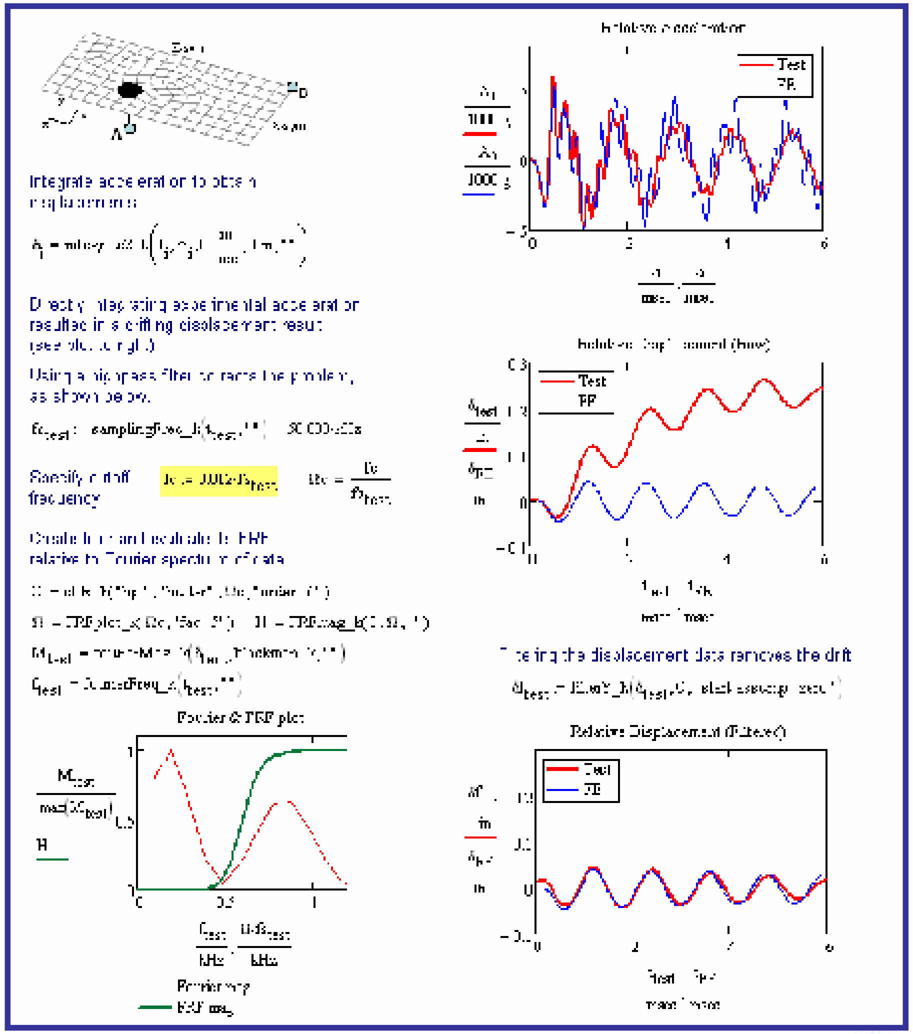
A Rich Library of Example Documents and Templates

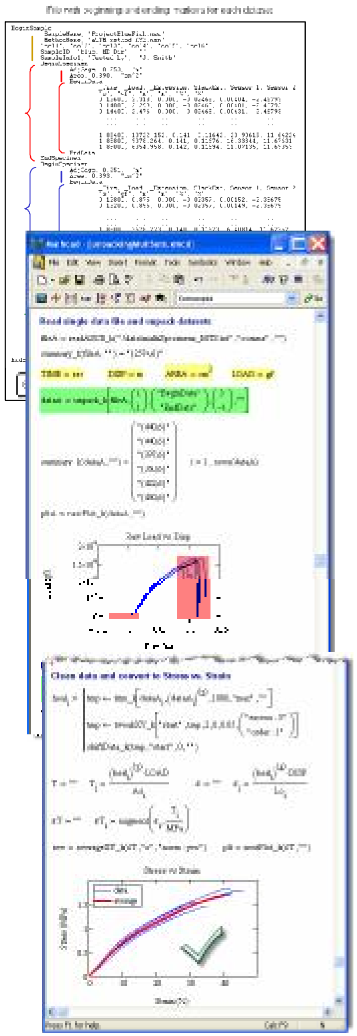
Examples and Templates:

- Walk user through the analysis process
- Reusable by user for their own data
- Fully customizable





Learn how to effectively work with your data!



Bodie Technology Inc

Training Seminars

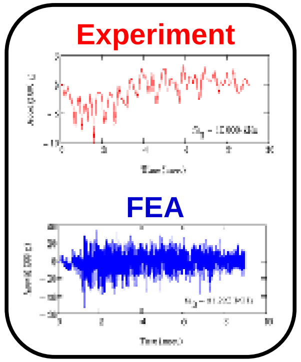
Learn how to get great results with confidence!

Introduction to Kornucopia® and Mathcad®

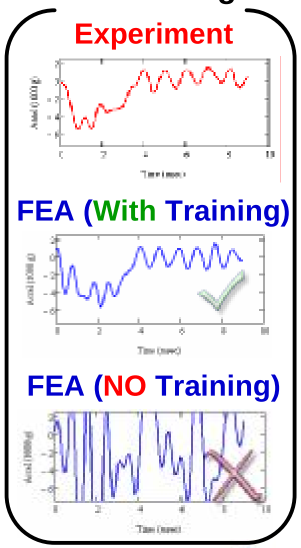
"Without Kornucopia® I really doubt the quality and quantity of work would have been what it was. The 1 on 1 instruction was invaluable."

Lieutenant Colonel Kelly Laughlin, PhD
US Army, Picatinny Arsenal

Raw Data



Decimation & Filtering



Analyzing Noisy Data via Filtering and DSP

"This DSP seminar should be mandatory for every explicit dynamics user. Ted is a great lecturer."

Pedro Bastias, NACCO – Matl's Handling Group

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Introduction to Kornucopia® and Mathcad®

Day 1 - Basics of Mathcad®

- What's possible with Mathcad® & Kornucopia®
  - Symbolics, numerical methods, data analysis, …
  - Analyzing challenging data
- Mathcad® basics
  - Worksheet layout and calculation order
  - Creating/editing math, graph, & text regions
  - Referenced worksheets and collapsed areas
- Working with units
  - In equations, plots, arrays, and data files
- Creating your first worksheets
  - Some simple calculations
  - Working with ASCII data files

Day 2 - Kornucopia® (Part 1)

- Arrays, range variables, and looping
  - Matrices, 2-D arrays, and nested arrays
  - Various ways to loop equations and functions
- Reading and writing data files
- Tips on using solve-blocks
- Easy-to-use programming within Mathcad®
  - *NO need to be a C or Scripting wizard!*

Day 2 Continued

- Kornucopia® features for analyzing challenging data
  - Functions & example worksheets
  - The ADV parameter
  - Accessing help and documentation
  - Connecting to the Kornucopia® library
- Enhanced file reading & writing
  - Working with "real-world" ASCII files with header text, stacked datasets, etc.
  - Unpacking data files

Day 3 - Kornucopia® (Part 2)

- Array and string manipulation
  - Reorder rows & cols, nested array tools, find locations in data that meet criteria, string manipulation & parsing
- Techniques for easily plotting multiple curves

Customizable to fit YOUR NEEDS with YOUR DATA

1-Day to 3-Day Formats

More details on our website
www.BodieTech.com

- Working with Excel and PowerPoint

Analyzing Noisy Data via Filtering and DSP

Day 1 Concepts of DSP, Filtering, and More

- Motivation for using DSP with experimental and/or simulation data
  - Workshop – experiencing common DSP errors
- DSP fundamentals
  - Data collection and sampling: avoiding aliasing
  - FFT's, Fourier Analysis, windows …
    – it is not a black box!
  - Lowpass, highpass, bandstop, bandpass filters
  - IIR and FIR filters, Butterworth & Chebyshev filters
  - Filter parameters: cutoff freq., filter order, single/double pass
  - Filter induced distortions, end effects & time delays
  - FRF (Filter Response Functions)
  - Decimation and upsampling
- DSP features in Kornucopia®
- DSP features within Abaqus
- Workshops
  - Learning to use DSP functions with simple signals
  - Computing derivatives & integrals from noisy data

Day 2 Applications of DSP (Part 1)

- Review of DSP fundamentals, solidifying key concepts
- Developing a DSP strategy for a given problem
- Working with experimental data and validation of simulation and/or experimental results
- DSP using various software
- Working with transient-dynamic events
  - Workshop – Transient impact analysis
  - Workshop – Salvaging shock data via hp filtering
  - Workshop – Penetration problem (comparing multiple models to test data)

Day 3 Applications of DSP (Part 2)

- Working with quasi-static models created using transient simulation techniques.

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Customizable to fit YOUR NEEDS with YOUR DATA

1-Day to 3-Day Formats

More details on our website
www.BodieTech.com

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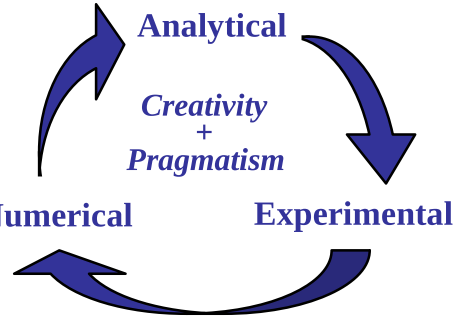
- more videos: www.BodieTech.com/videos

E-mail: info@BodieTech.com



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Specializing in solving complex problems in nonlinear mechanics by employing a proven mix of computational and testing knowledge in novel ways

- **Kornucopia® Software**
- **Customized Training**
- **Expert Consulting**